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U.S. DEPARTMENT OF COMMERCE / Environmental Science Services Administration

WEATHER BUREAU FORECASTERS HANDBOOK NO. 1 - FACSIMILE PRODUCTS

OFFICE OF
METEOROLOGICAL OPERATIONS

SILVER SPRING, MD.

U.S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU
SILVER SPRING, MD. 20910

December 29, 1967

IN REPLY REFER TO: W111

TO : All Recipients of "Weather Bureau Forecasters Handbook No. 1 - Facsimile Products"

FROM : Director, Weather Bureau

SUBJECT: Transmittal Memorandum for "Weather Bureau Forecasters Handbook No. 1 - Facsimile Products" Issuance 67-1

1. Material Transmitted:

First issuance under the new Weather Bureau Directives System of "WBFH No. 1 - Facsimile Products" (310 pages).

2. Summary:

This Handbook is the first in the series of Handbooks which will deal with the derivation of weather forecasts.

3. Effect on Other Instructions:

"WBFH No. 1 - Facsimile Products" replaces the draft copy of the Handbook distributed in June 1966. The binder and tabs issued with the draft copy may be used in assembling this version. Due to additions, however, there will be no tabs for sections SA-2A, SA-6, SA-7, SA-8, UA-3A, UA-7, SP-1A, UP-8A, UP-10A, UP-16, UP-17 UP-18, and NA-1A. They may be provided at a later date depending on planned revisions. Additionally, the index section has been simplified to consist only of the annotated facsimile schedules.

George P. Cressman

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U.S. DEPARTMENT OF COMMERCE
Alexander B. Trowbridge, Secretary

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
Robert M. White, Administrator

WEATHER BUREAU
George P. Cressman, Director

WEATHER BUREAU FORECASTERS HANDBOOK NO. 1
FACSIMILE PRODUCTS

OFFICE OF METEOROLOGICAL OPERATIONS
SILVER SPRING, MD.
FEBRUARY 1968

RECORD OF CHANGES

Change No./Date	Date Entered	Entered By
ch. 5	oct. 68	LD

INTRODUCTION

It has been said with some truth that meteorology is a science without a technology and that weather forecasting is presently an art rather than a science. Both of these characterizations describe the failure of our profession to achieve a state of organization in our scientific knowledge that will permit its systematic application to the generation of products and services required by current demand.

The organization and ordering of scientific knowledge for specific application is the goal of applied research. It is only within about the last decade that we have seen the initiation of research efforts aimed specifically at weather forecasting on a scale which the complexity and importance of the problem demand. Much progress has been made, particularly, in the development of mathematical models that reproduce rather well the gross features of atmospheric motions for periods of one or two days. But we have achieved only the crudest kinds of physical and statistical formulations of the weather forecast problem involving such elements as cloudiness, precipitation, temperature, and wind flow near the ground.

In spite of the fact that we do not have satisfactory techniques and methods for systematically deriving weather forecasts, it is essential that we set down in one place, in the proper form, what we do know about methods for making various kinds of forecasts. It is for this purpose that the original Forecasters Handbook was designed.

Recently, however, the Weather Bureau implemented a new Directives System. In this new System, the various technical instructions issued by the Weather Bureau will be called "handbooks". Thus, "Weather Bureau Forecasters Handbook Number 1 - Facsimile Products" is the first in the series of handbooks that will provide information and instruction in the derivation of weather forecasts. Specifically, "WBFH No. 1 - Facsimile Products" provides background information on the production of facsimile charts transmitted on the National, Weather Bureau Forecast Center, Honolulu, and High Altitude Facsimile Circuits. (Information on the charts transmitted on the Intra-Alaska Circuit will be added later.)

To use this Handbook one begins with one of the annotated fax schedules, obtains the Handbook number of the chart of interest and turns to the correspondingly labeled green tab. Usually only brief discussions and descriptions of the charts are provided, but references to more detailed information are frequently given.

It is planned to update the contents of the "Forecasters Handbook" series quarterly beginning with January.

The compilation of material included in this Handbook has involved the ideas and labors of a number of individuals and organizations of the Weather Bureau. Space does not permit the listing of all who helped in the preparation of the contents. However, without the participation of Mr. Edwin B. Fawcett of

the Analysis and Forecast Division of National Meteorological Center who supplied most of the technical descriptions of the NMC products, Julius Badner and Matthew H. Kulawiec of Technical Procedures Branch, Weather Analysis and Prediction Division, who prepared the final and original versions of the write-ups, this document could never have been developed. Technical editing and final organization were accomplished by Philip A. Calabrese of Technical Procedures Branch, Weather Analysis and Prediction Division.

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SELECTED ABBREVIATIONS

A&FD	Analysis and Forecast Division, NMC
AIREP	Air-Report
AIRINC	Aeronautical Radio Incorporated
ARTC	Air Route Traffic Control
AW	Airway Weather
BAMS	Bulletin of the American Meteorological Society
CAT	Clear Air Turbulence
CDC	Control Data Corporation
CRT	Cathode Ray Tube
FNWF	Fleet Numerical Weather Facility
ITC	Intertropical Convergence Zone
NAWAC	National Weather Analysis Center (Now NMC)
NESC	National Environmental Satellite Center
NMC	National Meteorological Center
NWP	Numerical Weather Prediction
PE	Primitive Equation
PEP	Primitive Equation Precipitation
PIBAL	Pilot Balloon
PIREPS	Pilot Reports
RADAT	Radar Data
RADU	Radar Unit
RAOB	Radiosonde Observation
RAWARC	Radar Warning Circuit
RAWIN	Rawinsonde
SELS	Severe Local Storms
SLYH	Sanders, LaRue, Younkin, Hovermale
TAFORS	Terminal Airport Forecasts
TOE	Top of Ekman (layer)
WBAS	Weather Bureau Airport Station

NATIONAL FACSIMILE SCHEDULE

Circuit WFX 1234

GMT	FAX NO.	HAND-BOOK NO.	FROM	Chart Description	TIME OR V.T. GMT
0002	1		WBC	Extended Forecast Charts	12
		E-2,3		Forecast 5 day (Mon-Wed-Fri)	
		E-4		Prog sfc 72 hr (Sun-Tue-Thu-Sat)	
		NA-2		Ice Chart*	
		E-5		30-day Outlook (1st & 15th)	
0042	2	NA-1A	WBC	Satellite Cloud Chart	
				Ern US to Wrn Atl (Mosaic)	
0050	3	SA-5	MKC	Ana' sis radar summary	00
0102	4	UP-4	WBC	Prog 500 mb 72 hr	12
0114	5	AC-6	WBC	Data snow cover/snowfall	00
0122	6	AC-4	WBC	Data maximum temperatures	00
0132	7	SA-1	WBC	Analysis surface 6 hrly	00
0207	8	UA-1	WBC	Analysis 500 mb	00
0219	9	SA-4	WBC	Analysis weather depiction	01
0237	10	UA-1	WBC	Analysis 850 mb	00
		AC-1	WBC	Analysis pressure change 12 hr	
0247	11	UP-1	WBC	Analysis vort+500 mb initial	
				Progs brtrpc 12 hr, 24 hr, 36 hr	
0302	12	SP-4	WBC	Prog surface, clds, + precip 12 hr	12
				Prog sig weather low lvl 24 hr	00
0312	13	AC-7	WBC	Data winds aloft - lower lvls	00
0322	14	AC-7	WBC	Data winds aloft - intmdt lvls	00
0332	15	AC-7	WBC	Data winds aloft - upper lvls	00
				Data tropopause	
0342	16	UA-1	WBC	Analysis 700 mb	00
0352	17	SA-5	MKC	Analysis radar summary	03
0404	18	AC-3	WBC	Analysis stability + precip water	00
				Freezing level - rel humidity	
0414	19	UP-10	WBC	Prog Trop max wind and wind shear	12
		UP-11	WBC	Prog sig weather	
0424	20	NA-1A	WBC	Satellite Cloud Chart	
				Wrn Pac to Wrn Atl (Mosaic)	
0434	21	SA-1	WBC	Analysis surface 3 hrly	03
0454	22	SA-3	WBC	Analysis surface 6 hrly	00
				with 1000-500 mb thickness	
0506	23	SA-4	WBC	Analysis weather depiction	04
0524	24	UA-6	WBC	Analysis maximum wind	00
				Analysis wind shear	
0534	25	UA-1	WBC	Analysis 300 mb	00
0544	26	UA-1	WBC	Analysis 200 mb	00
0554	27	SA-5	MKC	Analysis radar summary	05
0600	31	UA-2	WBC	Analysis 500 mb	00
0612	32	NA-1	WBC	Analysis nephanalysis (10 min)	
0622	33	NA-1	WBC	Analysis nephanalysis (16 min)	
0638	34	UA-2	WBC	Analysis 300 mb	00
0648	35	SA-5	MKC	Analysis radar summary	06
0700	36	UP-4	WBC	Prog 500 mb 36 hr	12
0712	37	UP-4	WBC	Prog 500 mb 24 hr, 48 hr	00
0722	38	UP-2	WBC	Analysis vert vel + 500 mb initial	
				Progs brclnc 12 hr, 24 hr, 36 hr	
0737	39	SA-3	WBC	Analysis surface 6 hrly	06
0812	40	SA-4	WBC	Analysis weather depiction	07
0830	41	SP-6	WBC	Prog QPF guidance and	
		SP-7	WBC	Prog heavy snow	
		AC-1	WBC	Analysis pressure change 12 hr	
0840	42	SP-3	WBC	Prog sfc, clds + precip 24 hr 48 hr	00
0850	43	SA-5	MKC	Analysis radar summary (6 min)	08
0900	44	AC-7	WBC	Data winds aloft - intmdt lvls	06
0910	45	AC-7	WBC	Data winds aloft - lower lvls	06
0920	46	UP-4	WBC	Prog 300 mb 24 hr	00
				200 mb 24 hr	
0930	47	UP-4	WBC	Prog 850 mb 24 hr	00
				700 mb 24 hr	
0940	48	AC-6	WBC	Data snowfall 6 hrly	
		AC-7	WBC	Data winds aloft - upper lvls	06
0950	49	SA-5	MKC	Analysis radar summary	09
1002	50	UP-10	WBC	Prog trop max wind and wind shear	18
		UP-11	WBC	Prog sig weather	
1012	51	UP-4	WBC	Prog 700 mb 36 hr	12
1022	52	SP-4	WBC	Prog surface, clds + precip 12-hr	18
				Prog sig weather low lvl 24-hr	06
1032	53	SA-1	WBC	Analysis surface 3 hrly	09
1052	54	SP-2	WBC	Prog surface, precip 30 hr	12
				Prog 1000-500 mb thickness 36 hr	
1102	55	UP-4	WBC	Prog 300 mb 36 hr	12
1112	56	SA-4	WBC	Analysis weather depiction	10
1130	57	SA-5	MKC	Analysis radar summary	11
1145	58	UA-4	WBC	Analysis 500 mb	00
1200	60	SP-9	MKC	Prog severe wx outlook (12Z-12Z)	
1210	61	SP-6	WBC	Prog QPF guidance and	
		SP-7	WBC	Prog heavy snow	
1220	62	SP-8	WBC	Forecasts temperature change	
1230	63		WBC	Genot	
1240	64	NA-1	WBC	Analysis nephanalysis	
1250	65	SA-5	MKC	Analysis radar summary	12
1302	66	UP-4	WBC	Prog 500 mb 72 hr	00
1314	67	AC-6	WBC	Data snow cover	12
1322	68	AC-4	WBC	Data minimum temperatures	12
1332	69	SA-1	WBC	Analysis surface 6 hrly	12
1407	70	UA-1	WBC	Analysis 500 mb	12
1419	71	SA-4	WBC	Analysis weather depiction	13
1437	72	UA-1	WBC	Analysis 850 mb	12
		AC-1	WBC	Analysis pressure change 12 hr	
1447	73	UP-1	WBC	Analysis vort + 500 mb, initial	
				Progs brtrpc 12 hr, 24 hr, 36 hr	
1502	74	SP-4	WBC	Prog surface, clds + precip 12 hr	00
				Prog sig weather low lvl 24 hr	12
1512	75	AC-7	WBC	Data winds aloft - lower lvls	12
1522	76	AC-7	WBC	Data winds aloft - intmdt lvls	12
1532	77	AC-5	WBC	Data rainfall 24 hr	12
1542	78	AC-7	WBC	Data winds aloft - upper lvls	12
				Data tropopause	
1552	79	UA-1	WBC	Analysis 700 mb	12
1602	80	SA-5	MKC	Analysis radar summary	15
1614	81	AC-3	WBC	Analysis stability + precip water	12
				Freezing level - rel humidity	
1624	82	UP-10	WBC	Prog trop max wind and wind shear	00
		UP-11	WBC	Prog sig weather	
1634	83	SA-1	WBC	Analysis surface 3 hrly	15
1654	84	SA-3	WBC	Analysis surface 6 hrly	12
				with 1000-500 mb thickness	
1706	85	SA-4	WBC	Analysis weather depiction	16
1724	86	UA-6	WBC	Analysis maximum wind	12
				Analysis wind shear	
1734	87	UA-1	WBC	Analysis 300 mb	12
1744	88	UA-1	WBC	Analysis 200 mb	12
1754	89	UA-2	WBC	Analysis 500 mb	12
1806	91			Circuit lineup (1806-1842Z)	
1842	92	SA-5	MKC	Analysis radar summary	18
1854	93	UA-2	WBC	Analysis 300 mb	12
1904	94	UP-4	WBC	Prog 500 mb 36 hr	00
1916	95	UP-4	WBC	Prog 500 mb 24 hr, 48 hr	12
1926	96	UP-2	WBC	Analysis vert vel + 500 mb initial	
				Prog brclnc 12 hr, 24 hr, 36 hr	
1941	97	SA-3	WBC	Analysis surface 6 hrly	18
2016	98	SA-4	WBC	Analysis weather depiction	19
2034	99	AC-1	WBC	Analysis pressure change 12 hr	
		SP-6	WBC	Prog QPF guidance and	
		SP-7	WBC	Prog heavy snow	
2044	100	SP-3	WBC	Prog sfc, clds + precip 24 hr 48 hr	12
2054	101	SA-5	MKC	Analysis radar summary (6 min)	20
2100	102	AC-7	WBC	Data winds aloft - intmdt lvls	18
2110	103	AC-7	WBC	Data winds aloft - lower lvls	18
2120	104	UP-4	WBC	Prog 300 mb 24 hr	12
				200 mb 24 hr	12
2130	105	UP-4	WBC	Prog 850 mb 24 hr	12
				700 mb 24 hr	12
2140	106	AC-6	WBC	Data snowfall 6 hrly	
		AC-7	WBC	Data winds aloft - upper lvls	18
2150	107	SA-5	MKC	Analysis radar summary	21
2202	108	UP-10	WBC	Prog trop max wind and wind shear	06
		UP-11	WBC	Prog sig weather	
2212	109	UP-4	WBC	Prog 700 mb 36 hr	00
2222	110	SP-4	WBC	Prog surface, clds + precip 12 hr	06
				Prog sig weather low level 24 hr	18
2232	111	SA-1	WBC	Analysis surface 3 hrly	21
2252	112	SA-5	MKC	Analysis radar summary	22
2258	113	SP-2	WBC	Prog surface, precip 30 hr	00
				Prog 1000-500 thickness 36 hr	
2308	114	UP-4	WBC	Prog 300 mb 36 hr	00
2318	115	SA-4	WBC	Analysis weather depiction	22
2336	116	NA-1	WBC	Analysis nephanalysis	
2346	117	SP-7	WBC	Prog heavy snow	
		SP-8	WBC	Forecasts temperature change	
2356	118	SA-5	MKC	Analysis radar summary	23

*Sent following the 72-hr surface prog on Sunday, Tuesday, or Thursday Only. Chart will not be sent when 1st or 15th falls on these days.

HIGH ALTITUDE FACSIMILE SCHEDULE

Circuit GF 10200

GMT	FAX NO.	HAND-BOOK NO.	FROM	Chart Description	TIME OR V.T. GMT
0004	301				
0010	302	UP-13	SFO	Progs composite 700 & 500 mb	12
0020	303	UP-13	SFO	Progs composite 300, 200 mb & sig weather (sfc-150 mb)	12
0031	304	UP-5	WBC	Prog 500 mb 30 hr	18
0041	305	UP-5	WBC	Prog 300 mb 30 hr	18
0051	306	UP-5	WBC	Prog 200 mb 30 hr	18
0101	307	UP-5	WBC	Prog 700 mb 30 hr	18
0111	308	UP-15	MIA	Prog sig weather (500-150 mb)	12
0121	309	UP-15	MIA	Prog 300 mb	12
0131	310	UP-15	MIA	Prog 200 mb	12
0141	311	UP-15	MIA	Prog 500 mb	12
0151	312	NA-1A	WBC	Data satellite Wrn No America-NE Pac (Mosaic)	
0201	313		UO	Prog sig weather (400-150 mb)	12
0211	314	UP-14	JFK	Prog sig weather (700-150 mb)	12
0219	315	UP-11	WBC	Prog sig weather (400-150 mb)	12
0227	316	UP-12	ANC	Prog sig weather (700-150 mb)	12
0234	317	UP-5	WBC	Prog 700 mb 24 hr	12
0300	318	SA-2	WBC	Analysis preliminary surface	00
0320	319				
0335	320	NA-1A	WBC	Data satellite East equatorial Pacific (Mosaic)	
0350	321	NA-1A	WBC	Data satellite United States (Mosaic)	
0400	322	UA-3	WBC	Analysis 500 mb	00
0420	323	SP-1	WBC	Prog surface 30 hr	18
0446	324	UP-13	SFO	Progs composite 700 & 500 mb	18
0456	325	UP-13	SFO	Progs composite 300, 200 mb & sig weather (sfc-150 mb)	18
0507	326	NA-1	WBC	Data satellite#	
0517	327	UA-3	WBC	Analysis 300 mb	00
0524	328			Test period*	
0536	329	UP-15	MIA	Prog sig weather (500-150 mb)	18
0546	330	UP-15	MIA	Prog 300 mb	18
0556	331	UP-15	MIA	Prog 200 mb	18
0606	332	UP-15	MIA	Prog 500 mb	18
0616	333	NA-1A	WBC	Data satellite South Pacific (Mosaic)	
0626	334				
0633	335	UP-8A	WBC	Prog 500 mb 0 & 24 hr vort & 24 hr 700 mb vert vel	00
0643	336	UP-9	WBC	Prog 300 mb 18 hr	18
0709	337	UP-10A	WBC	Prog trop-vert wind shear 18 hr	18
0735	338	UP-9	WBC	Prog 500 mb 18 hr	18
0801	339	UP-9	WBC	Prog 700 mb 18 hr	18
0827	340		UO	Prog sig weather (400-150 mb)	18
0837	341	UP-14	JFK	Prog sig weather (700-150 mb)	18
0845	342	UP-11	WBC	Prog sig weather (400-150 mb)	18
0853	343	UP-12	ANC	Prog sig weather (700-150 mb)	18
0900	344	SA-2	WBC	Analysis preliminary surface	06
0920	345	UP-9	WBC	Prog 700 mb	00
0930	346	UP-5	WBC	Prog 200 mb 24 hr	00
0940	347	NA-1A	WBC	Data satellite North Pacific (Mosaic)	
0950	348	UP-16	HNL	Progs composite 300 & 200 mb	00
1010	349				
1012	350	UP-16	HNL	Progs composite 500 mb & sig weather (sfc-150 mb)	00
1021	351	UP-9	WBC	Prog 300 mb 24 hr	00
1047	352	UP-10A	WBC	Prog trop-vert wind shear 24 hr	00
1112	353	UP-9	WBC	Prog 500 mb 24 hr	00
1138	354	SP-1	WBC	Prog surface 24 hr	00
1204	355	NA-1A	WBC	Data satellite North Pacific (Mosaic)	
1214	356	UP-13	SFO	Progs composite 700 & 300 mb	00
1224	357	UP-13	SFO	Progs composite 300, 200 mb & sig weather (sfc-150 mb)	00
1235	358	UP-5	WBC	Prog 500 mb 30 hr	06
1245	359	UP-5	WBC	Prog 300 mb 30 hr	06
1255	360	UP-5	WBC	Prog 200 mb 30 hr	06
1305	361	UP-5	WBC	Prog 700 mb 30 hr	06
1315	362	UP-15	MIA	Prog sig weather (500-150 mb)	00
1325	363	UP-15	MIA	Prog 300 mb	00
1335	364	UP-15	MIA	Prog 200 mb	00
1345	365	UP-15	MIA	Prog 500 mb	00
1355	366				
1401	367		UO	Prog sig weather (400-150 mb)	00
1411	368	UP-4	JFK	Prog sig weather (700-150 mb)	00
1419	369	UP-11	WBC	Prog sig weather (400-150 mb)	00
1427	370	UP-12	ANC	Prog sig weather (700-150 mb)	00
1434	371	UP-9	WBC	Prog 700 mb 24 hr	00
1500	372	SA-2	WBC	Analysis preliminary surface	12
1520	373	NA-1A	WBC	Data satellite European Northeastern Asia (Mosaic)	
1530	374		WBC	Genot	
1540	375	SP-2	WBC	Prog surface 30 hr	06
1606	376	UA-3	WBC	Analysis 500 mb	12
1626	377			Circuit lineup	
1725	378	UP-13	SFO	Progs composite 700 & 500 mb	06
1735	379	UP-13	SFO	Progs composite 300, 200 mb & sig weather (sfc-150 mb)	06
1746	380	UP-15	MIA	Prog sig weather (500-150 mb)	06
1756	381	UP-15	MIA	Prog 300 mb	06
1806	382	UP-15	MIA	Prog 200 mb	06
1816	383	UP-15	MIA	Prog 500 mb	06
1826	384	UA-1	WBC	Analysis 300 mb	12
1833	385	UP-8A	WBC	Prog 500 mb 0 & 24 hr vort & 24 hr 700 mb vert vel	12
1843	386	UP-9	WBC	Prog 300 mb 18 hr	06
1909	387	UP-10A	WBC	Prog trop vert wind shear 18 hr	06
1935	388	UP-9	WBC	Prog 500 mb 18 hr	06
2001	389	UP-9	WBC	Prog 700 mb 18 hr	06
2027	390		UO	Prog sig weather (400-150 mb)	06
2037	391	UP-14	JFK	Prog sig weather (700-150 mb)	06
2045	392	UP-11	WBC	Prog sig weather (400-150 mb)	06
2053	393	UP-12	ANC	Prog sig weather (700-150 mb)	06
2100	394	SA-2	WBC	Analysis preliminary surface	18
2120	395	UP-9	WBC	Prog 700 mb 24 hr	12
2130	396	UP-5	WBC	Prog 200 mb 24 hr	12
2140	397	NA-1A	WBC	Data satellite Arctic North Pole (Mosaic)	
2150	398	UP-16	HNL	Progs composite 300 & 200 mb	12
2210	399				
2212	400	UP-16	HNL	Prog composite 500 mb & sig weather (sfc-150 mb)	12
2221	401	UP-9	WBC	Prog 300 mb 24 hr	12
2247	402	UP-10A	WBC	Prog trop vert wind shear 24 hr	12
2312	403	UP-9	WBC	Prog 500 mb 24 hr	12
2338	404	SP-1	WBC	Prog surface 24 hr	12

NOTES: #Data as available to meet requirements. Times of data, areas of coverage, map projections, etc., variable.

*ANC TEST ON SUNDAY
WBC TEST ON MONDAY
JFK TEST ON TUESDAY
MIA TEST ON WEDNESDAY
SFO TEST ON THURSDAY
WWV TEST ON FRIDAY (TIME SIGNAL)
UO TEST ON SATURDAY

PACIFIC/CONTINENTAL FACSIMILE SCHEDULE

Circuit GF 10206

GMT	FAX NO.	HAND-BOOK NO.	Chart Description	TIME OR V.T. GMT
0000	900	E-1	5-Day Observed	
0010	901			
0025	902	NA-1A	Satellite Cloud Chart 60W-120W (Mosaic)	
0045	902A	NA-1A	Satellite Cloud Chart Ern Pac-Wrn U.S. (Mosaic)	
0055	903			
0120	904	NA-1	Analysis nephanalysis	
0140	905			
0220	906			
0230	907	UA-1	Analysis 700 mb w/d	00
0240	908	UA-5	Analysis sfc and 1000-500 mb thickness	00
		AC-2	Analysis 500 mb height change 24 hr	00
0250	909	UA-1	Analysis 850 mb w/d	00
0300	911	SA-2	Analysis preliminary surface w/d	00
0320	912	UA-3A	Analysis 850 mb chart (no data)	00
0340	913	NA-1	Analysis nephanalysis	
0400	914			
0420	915	UA-5	Analysis 1000-500 mb thickness w/d	00
0440	916	SA-1	Analysis surface 3 hrly (sectional)	03
0450	916A			
0500	917	UA-3	Analysis 500 mb w/d	00
0520	918			
0528	919	UA-3	Analysis 300 mb w/d	00
0548	921	UA-3	Analysis 700 mb w/d	00
0608	922	UA-3	Analysis 200 mb w/d	00
0628	923	UP-4	Prog 500 mb baroclinic 12 hr	12
0640	924	UA-2	Analysis initial 500 mb vorticity	00
0650	925			
0655	926	UP-4	Prog 300/200 mb 24 hr	00
0705	927	UP-8	Prog 500 mb vorticity 24 hr	00
0715	928	UP-4	Prog 700/850 mb 24 hr	00
0725	929	UP-5	Prog 300/500 mb 24 hr	00
0740	931	SP-1	Prog surface 24 hr	00
0752	932	SP-1	Prog surface 36 hr	12
0804	933	UP-4	Prog 500 mb 72 hr	00
0816	934	UP-3	Analysis initial Prog 12, 18, 24 hr mean R. H.	
0822	935			
0830	936	SP-3	Prog surface Package A	
		SP-5		
		SP-8		
0900	937	SA-2	Analysis preliminary surface w/d	06
0935	939	UP-7	Analysis initial Prog 12, 24, 36 hr lifted index	
0950	941			
1000	942			
1010	943			
1020	944			
1040	945	SA-1	Analysis surface 3 hrly (sectional)	09
1050	945A			
1100	946	UP-6	Forecast Error Charts 500 mb 36 hr	12
1110	947			
1120	948			
1140	949			
1200	950	NA-1A	Satellite Cloud Chart 170E-130W (Mosaic)	
1220	950A	NA-1	Analysis nephanalysis	
1240	951		Genot	
1255	952			
1300	953		Circuit lineup	
1400	954			
1415	955	AC-5	Data prelim precip 24 hr	12
1425	956			
1430	957	UA-1	Analysis 700 mb w/d	12
1440	958	UA-5	Analysis surface with 1000-500 mb thickness	12
1450	959	UA-1	Analysis 850 mb w/d	12
1500	961	SA-2	Analysis preliminary surface	12
1520	962			
1530	963	NA-1	Analysis nephanalysis	
1600	964			
1620	965	UA-5	Analysis 1000-500 mb thickness w/d	12
1640	966	SA-1	Analysis surface 3 hrly (sectional)	15
1650	966A			
1700	967	UA-3	Analysis 500 mb w/d	12
1720	968	NA-1	Analysis nephanalysis	
1728	969	UA-3	Analysis 300 mb w/d	12
1748	971	UA-3	Analysis 700 mb w/d	12
1808	972	UA-3	Analysis 200 mb w/d	12
1828	973	UP-4	Prog 500 mb baroclinic 12 hr	00
1840	974	UA-2	Analysis initial 500 mb vorticity	12
1850	975			
1855	976	UP-4	Prog 300/200 mb 24 hr	12
1905	977	UP-8	Prog 500 mb vorticity 24 hr	12
1915	978	UP-4	Prog 700/850 mb 24 hr	12
1925	979	UP-5	Prog 300/500 mb 24 hr	12
1940	981	SP-1	Prog surface 24 hr	12
1952	982	SP-1	Prog surface 36 hr	00
2004	983	UP-4	Prog 500 mb 72 hr	00
2016	984	UP-3	Analysis initial Prog 12, 18, 24 hr mean R.H.	
2022	985			
2030	986	SP-3	Prog surface Package B	
		SP-5		
		SP-8		
2100	987	SA-2	Analysis preliminary surface w/d	18
2120	988	E-2	Extended forecast 5-day anomalies	
2130	989	E-3	Progs 5-day	12
		E-4	Prog sfc extended forecast 72 hr	12
2150	991	E-2	Prog sfc and 700 mb and 5 day mean	
2200	992	UP-7	Analysis initial Prog 12, 24, 36 hr lifted index	
2215	993	NA-1A	Satellite Cloud Chart Ern US-Wrn Europe (Mosaic)	
2225	994	NA-1A	Satellite Cloud Chart Polar Centered 40N-60W (Mosaic)	
2245	995	SA-1	Analysis surface 3 hrly (sectional)	21
2255	995A			
2300	996	UP-6	Forecast Error Charts 500 mb 36 hr	00
2310	997			
2320	998	NA-1A	Satellite Cloud Chart 20W-100W (Mosaic)	
2340	999	NA-1	Analysis nephanalysis	

NOTES: 1. All transmissions from WBC.

2. Numbers 910, 920, 930, 940, 960, 970, 980, and 990 will not be used.

3. w/d = with data.

ATLANTIC/CONTINENTAL FACSIMILE SCHEDULE

Circuit GF 10207

GMT	FAX NO.	HAND-BOOK NO.	Chart Description	TIME OR V.T. GMT
0000	800	E-1	5 day observed	
0010	801			
0025	802	NA-1A	Satellite Cloud Chart 60W-120W (Mosaic)	
0045	802A	NA-1A	Satellite Cloud Chart Ern Pac-Wrn U. S. (Mosaic)	
0055	803			
0120	804	NA-1	Analysis nephanalysis	
0140	805			
0220	806			
0230	807	UA-1	Analysis 700 mb w/d	00
0240	808	UA-5	Analysis sfc and 1000-500 mb thickness	00
		AC-2	Analysis 500 mb height change 24 hr	00
0250	809	UA-1	Analysis 850 mb w/d	00
0300	811	SA-2	Analysis preliminary surface w/d	00
0320	812			
0340	813	NA-1	Analysis nephanalysis	
0400	814			
0420	815	UA-5	Analysis 1000-500 mb thickness w/d	00
0440	816	SA-1	Analysis surface 3 hrly (sectional)	03
0450	816A			
0500	817	UA-3	Analysis 500 mb w/d	00
0520	818			
0528	819	UA-3	Analysis 300 mb w/d (240 SPM)	00
0540	821	UA-3	Analysis 700 mb (240 SPM)	00
0552	822	UA-3	Analysis 200 mb (240 SPM)	00
0618	823	UP-4	Prog 500 mb baroclinic 12 hr (240 SPM)	12
0630	824	UA-2	Analysis initial 500 mb vort (240 SPM)	00
0640	825			
0645	826	UP-4	Prog 300/200 mb 24 hr (240 SPM)	00
0655	827	UP-8	Prog 500 mb vorticity 24 hr (240 SPM)	00
0705	828	UP-4	Prog 700/850 mb 24 hr (240 SPM)	00
0715	829			
0730	831	SP-1	Prog surface 24 hr (240 SPM)	00
0740	832	SP-1	Prog surface 36 hr (240 SPM)	12
0750	833	UP-4	Prog 500 mb 72 hr (240 SPM)	00
0805	834	UP-3	Analysis initial Prog 12, 18, 24 hr mean R. H. (240 SPM)	
0822	835			
0830	836	SP-3	Prog surface Package A	
		SP-5		
		SP-8		
0900	837	SA-2	Analysis preliminary surface w/d	06
0935	839	UP-7	Analysis initial Prog 12, 24, 36 hr lifted index	
0950	841			
1000	842			
1010	843			
1020	844			
1040	845	SA-1	Analysis surface 3 hrly (sectional)	09
1050	845A			
1100	846	UP-6	Forecast Error Charts 500 mb 36 hr	12
1110	847	SP-10	Progs sea surface 12 hr, 36 hr	00
1120	848			
1140	849			
1200	850	NA-1A	Satellite Cloud Chart 170E-130W (Mosaic)	
1220	850A	NA-1	Analysis nephanalysis	
1240	851		Genot	
1255	852			
1300	853		Circuit lineup	
1400	854			
1415	855	AC-5	Data prelim precip 24 hr	12
1425	856			
1430	857	UA-1	Analysis 700 mb w/d	12
1440	858	UA-5	Analysis sfc and 1000-500 mb thickness	12
		AC-2	Analysis 500 mb height change 24 hr	12
1450	859	UA-1	Analysis 850 mb w/d	12
1500	861	SA-2	Analysis preliminary surface w/d	12
1520	862			
1530	863	NA-1	Analysis nephanalysis	
1600	864			
1620	865	UA-5	Analysis 1000-500 mb thickness w/d	12
1640	866	SA-1	Analysis surface 3 hrly (sectional)	15
1650	866A			
1700	867	UA-3	Analysis 500 mb w/d	12
1720	868	NA-1	Analysis nephanalysis	
1728	869	UA-3	Analysis 300 mb w/d (240 SPM)	12
1740	871	UA-3	Analysis 700 mb (240 SPM)	12
1752	872	UA-3	Analysis 200 mb (240 SPM)	12
1818	873	UP-4	Prog 500 mb baroclinic 12 hr (240 SPM)	00
1830	874	UA-2	Analysis initial 500 mb vort (240 SPM)	12
1840	875			
1845	876	UP-4	Prog 300/200 mb 24 hr (240 SPM)	12
1855	877	UP-8	Prog 500 mb vorticity 24 hr (240 SPM)	12
1905	878	UP-4	Prog 700/850 mb 24 hr (240 SPM)	12
1915	879			
1930	881	SP-1	Prog surface 24 hr (240 SPM)	12
1940	882	SP-1	Prog surface 36 hr (240 SPM)	00
1950	883	UP-4	Prog 500 mb 72 hr (240 SPM)	12
2005	884	UP-3	Analysis initial Prog 12, 18, 24 hr mean R. H. (240 SPM)	
2030	886	SP-3	Prog surface Package B	
		SP-5		
		SP-8		
2100	887	SA-2	Analysis preliminary surface w/d	18
2120	888	E-2	Extended Forecast 5 day Anomalies	
2130	889	E-3	Progs 5 day	12
		E-4	Prog sfc extended forecast 72 hr	12
2150	891	E-2	Prog sfc and 700 mb 5 day mean	
2200	892	UP-7	Analysis initial Prog 12, 24, 36 hr lifted index	
2215	893	NA-1A	Satellite Cloud Cover Ern US-Wrn Europe (Mosaic)	
2225	894	NA-1A	Satellite Cloud Cover Polar Centered 40N-60W (Mosaic)	
2245	895	SA-1	Analysis surface 3 hrly (sectional)	21
2255	895A			
2300	896	UP-6	Forecast Error Charts 500 mb 36 hr	00
2310	897	SP-10	Progs sea surface 12 hr, 36 hr	12
2320	898	NA-1A	Satellite Cloud Chart 20W-100W (Mosaic)	
2340	899	NA-1	Analysis nephanalysis	

NOTES: 1. All transmissions from WBC.

2. Numbers 810, 820, 830, 840, 860, 870, 880, and 890 will not be used.

3. w/d = with data.

GULF/CONTINENTAL FACSIMILE SCHEDULE

Circuit GF 10208

GMT	FAX NO.	HAND-BOOK NO.	Chart Description	TIME OR V.T. GMT
0000	800	E-1	5-Day Observed	
0010	801			
0025	802	NA-1A	Satellite Cloud Chart 60W-120W (Mosaic)	
0045	802A	NA-1A	Satellite Cloud Chart Ern Pac-Wrn U.S. (Mosaic)	
0055	803			
0120	804	NA-1	Analysis nephanalysis	
0140	805			
0220	806			
0230	807	UA-1	Analysis 700 mb w/d	00
0240	808	UA-5	Analysis sfc and 1000-500 mb thickness	00
		AC-2	Analysis 500 mb height change 24 hr	00
0250	809	UA-1	Analysis 850 mb w/d	00
0300	811	SA-2	Analysis preliminary surface w/d	00
0320	812			
0340	813	NA-1	Analysis nephanalysis	
0400	814			
0420	815	UA-5	Analysis 1000-500 mb thickness w/d	00
0440	816	SA-1	Analysis surface 3 hrly (sectional)	03
0450	816A			
0500	817	UA-3	Analysis 500 mb w/d	00
0520	818			
0528	819	UA-3	Analysis 300 mb w/d	00
0548	821	UA-3	Analysis 700 mb	00
0608	822	UA-3	Analysis 200 mb	00
0628	823	UP-4	Prog 500 mb baroclinic 12 hr	12
0640	824	UA-2	Analysis initial 500 mb vorticity	00
0650	825			
0655	826	UP-4	Prog 300/200 24 hr	00
0705	827	UP-8	Prog 500 mb vorticity 24 hr	00
0715	828	UP-4	Prog 700/850 mb 24 hr	00
0725	829			
0740	831	SP-1	Prog surface 24 hr	00
0752	832	SP-1	Prog surface 36 hr	12
0804	833	UP-4	Prog 500 mb 72 hr	00
0816	834	UP-3	Analysis initial Prog 12, 18, 24 hr mean R. H.	
0822	835			
0830	836	SP-3	Prog surface Package A	
		SP-5		
		SP-8		
0900	837	SA-2	Analysis preliminary surface w/d	06
0935	839	UP-7	Analysis initial Prog 12, 24, 36 hr lifted index	
0950	841			
1000	842			
1010	843			
1020	844			
1040	845	SA-1	Analysis surface 3 hrly (sectional)	09
1050	845A			
1100	846	UP-6	Forecast Error Charts 500 mb 36 hr	12
1110	847	SP-10	Progs sea surface 12 hr, 36 hr	00
1120	848			
1140	849			
1200	850	NA-1A	Satellite Cloud Chart 170E-130W (Mosaic)	
1220	850A	NA-1	Analysis nephanalysis	
1240	851		Genot	
1255	852			
1300	853		Circuit lineup	
1400	854			
1415	855	AC-5	Data prelim precip 24 hr	12
1425	856			
1430	857	UA-1	Analysis 700 mb w/d	12
1440	858	UA-5	Analysis sfc and 1000-500 mb thickness	12
		AC-2	Analysis 500 mb height change 24 hr	12
1450	859	UA-1	Analysis 850 mb w/d	12
1500	861	SA-2	Analysis preliminary surface w/d	12
1520	862			
1530	863	NA-1	Analysis nephanalysis	
1600	864			
1620	865	UA-5	Analysis 1000-500 mb thickness w/d	12
1640	866	SA-1	Analysis surface 3 hrly (sectional)	15
1650	866A			
1700	867	UA-3	Analysis 500 mb w/d	12
1720	868	NA-1	Analysis nephanalysis	
1728	869	UA-3	Analysis 300 mb w/d	12
1748	871	UA-3	Analysis 700 mb	12
1808	872	UA-3	Analysis 200 mb	12
1828	873	UP-4	Prog 500 mb baroclinic 12 hr	00
1840	874	UA-2	Analysis initial 500 mb vorticity	12
1850	875		Open	
1855	876	UP-4	Prog 300/200 mb 24 hr	12
1905	877	UP-8	Prog 500 mb vorticity 24 hr	12
1915	878	UP-4	Prog 700/850 mb 24 hr	12
1925	879			
1940	881	SP-1	Prog surface 24 hr	12
1952	882	SP-1	Prog surface 36 hr	00
2004	883	UP-4	Prog 500 mb 72 hr	12
2016	884	UP-3	Analysis initial Prog 12, 18, 24 hr mean R. H.	
2030	886	SP-3	Prog surface Package B	
		SP-5		
		SP-8		
2100	887	SA-2	Analysis preliminary surface w/d	18
2120	888	E-2	Extended forecast 5-day anomalies	
2130	889	E-3	Progs 5 day	12
		E-4	Prog sfc extended forecast 72 hr	12
2150	891	E-2	Prog sfc and 700 mb 5 day mean	
2200	892	UP-7	Analysis initial Prog 12, 24, 36 hr lifted index	
2215	893	NA-1A	Satellite Cloud Chart Ern US-Wrn Europe (Mosaic)	
2225	894	NA-1A	Satellite Cloud Chart Polar Centered 40N-60W (Mosaic)	
2245	895	SA-1	Analysis surface 3 hrly (sectional)	21
2255	895A			
2300	896	UP-6	Forecast Error Charts 500 mb 36 hr	00
2310	897	SP-10	Progs sea surface 12 hr, 36 hr	12
2320	898	NA-1A	Satellite Cloud Chart 20W-100W (Mosaic)	
2340	899	NA-1	Analysis nephanalysis	

NOTES: 1. All transmissions from WBC.

2. Numbers 810, 820, 830, 840, 860, 870, 880, and 890 will not be used.

3. w/d = with data.

SOUTH ATLANTIC COASTAL FACSIMILE SCHEDULE

Circuit GF 10209

GMT	FAX NO.	HAND-BOOK NO.	FROM	Chart Description	TIME OR V.T. GMT
0000	2401				
0015	2402	NA-1	WBC	Analysis nephanalysis	
0030	2403	NA-1	WBC	Analysis nephanalysis	
0100	2404	NA-1	WBC	Analysis nephanalysis	
0132	2405				
0200	2406				
0230	2407				
0300	2408	NA-1A	WBC	Satellite Equatorial Mosaic #3	
0330	2409				
0345	2410		WBC	Satellite Winds-Wrn Hem (Exper)	00
0415	2411				
0500	2412	UA-7	MIA	Data 850 mb	00
0511	2413	UA-7	MIA	Data 700 mb	00
0522	2414	UA-7	MIA	Data 300 mb	00
0533	2415		WBC	Analysis 500 mb (Exper) Sec 0	00
0546	2416		WBC	Analysis 500 mb (Exper) Sec 1	00
0559	2417		WBC	Analysis 300 mb (Exper) Sec 0	00
0612	2418				
0616	2419	SA-7	MIA	Analysis surface (1:10 M)	00
0656	2420	UA-7	MIA	Analysis 200 mb	00
0716	2421	SA-8	MIA	Analysis Top-Of-Ekman Layer (TOE)	00
0736	2422	UA-7	MIA	Analysis 500 mb	00
0746	2423		WBC	Analysis 200 mb (Exper) Sec 0	00
0759	2424		WBC	Analysis 700 mb (Exper) Sec 0	00
0811	2425	NA-1	WBC	Analysis nephanalysis	
0830	2426	SA-2A	WBC	Data final surface	00
0845	2427				
0915	2428	SA-7	MIA	Analysis surface (1:10 M)	06
0955	2429	NA-1A	WBC	Satellite Equatorial Mosaic #4	
1010	2430				
1030	2431				
1100	2432				
1130	2433	SA-2A	WBC	Data final surface	06
1145	2434	NA-1A	WBC	Satellite Equatorial Mosaic #5	
1200	2435				
1215	2436				
1230	2437				
1300	2438			Circuit lineup	
1400	2439		WBC	Genot	
1410	2440				
1430	2441	NA-1	WBC	Analysis Nephanalysis Australia-New Zealand	
1500	2442				
1515	2443				
1545	2444		WBC	Satellite Winds-Ern Hem (Exper)	12
1615	2445				
1645	2446				
1700	2447	UA-7	MIA	Data 850 mb	12
1711	2448	UA-7	MIA	Data 300 mb	12
1722	2449	UA-7	MIA	Data 700 mb	12
1733	2450		WBC	Analysis 500 mb (Exper) Sec 0	12
1746	2451		WBC	Analysis 500 mb (Exper) Sec 1	12
1759	2452		WBC	Analysis 300 mb (Exper) Sec 0	12
1812	2453		WBC	Analysis 200 mb (Exper) Sec 0	12
1823	2454				
1826	2455	SA-7	MIA	Analysis surface (1:10 M)	12
1906	2456	UA-7	MIA	Analysis 200 mb	12
1926	2457	SA-8	MIA	Analysis Top-Of-Ekman Layer (TOE)	12
1946	2458	UA-7	MIA	Analysis 500 mb	12
1956	2459				
2000	2460	SA-2A	WBC	Data final surface	12
2015	2461	NA-1A	WBC	Satellite Equatorial Mosaic #1	
2030	2462	NA-1A	WBC	Satellite Equatorial Mosaic (Enhanced) #7	
2045	2463		WBC	Analysis 700 mb (Exper) Sec 0	12
2058	2464		WBC	Prog 700 mb (Exper) Sec 0	12
2110	2465				
2123	2466	SA-7	MIA	Analysis surface (1:10 M)	18
2205	2467		WBC	Prog 300 mb (Exper) Sec 0	12
2218	2468		WBC	Prog 300 mb (Exper) Sec 1	12
2230	2469	SA-2A	WBC	Data final surface	18
2245	2470	NA-1	WBC	Analysis nephanalysis	
2308	2471				
2323	2472	NA-1A	WBC	Satellite Equatorial Mosaic #2	
2338	2473	NA-1A	WBC	Satellite Equatorial Mosaic (Enhanced) #8	
2353	2474				

HONOLULU RADIO

KVM 70

GMT	HAND-BOOK NO.	FROM	Chart Description	TIME OR V.T. GMT
0838		HNL	Test/Announcement Chart	-
0900	UP-18	HNL	Prog 700 mb	00
0900	UP-16	HNL	Prog significant weather	00
0923	UP-16	HNL	Prog 500 mb	00
0923	UP-17	HNL	Prog 250 mb	00
0946	UP-16	HNL	Prog 300 mb	00
0946	UP-16	HNL	Prog 200 mb	00
1009	SA-6	HNL	Analysis surface	06
2038		HNL	Test/Announcement Chart	-
2100	UP-18	HNL	Prog 700 mb	12
2100	UP-16	HNL	Prog significant weather	12
2123	UP-16	HNL	Prog 500 mb	12
2123	UP-17	HNL	Prog 250 mb	12
2146	UP-16	HNL	Prog 300 mb	12
2146	UP-16	HNL	Prob 200 mb	12
2209	SA-6	HNL	Analysis surface	18

SA-1; SURFACE ANALYSIS

Plotted and analyzed by hand, North American area at 1:10 million scale for 0000Z plus each 3 hours.

Plotting Procedures

1. NETWORKS:

Standard Network with no substitutions is used over United States 48 states only (see appendix 1). Elsewhere the data are plotted as available. Over Pacific Ocean, surface ship bulletins usually arrive at NMC as analysis is being finalized (i.e., 1 1/4 to 1 1/2 hours after observation time). Ship reports are entered on the analysis acetate when time does not permit plotting them on the manuscript chart. Therefore, these ship data are seen by analysts only very briefly before chart deadline.

2. MODEL:

Plotting model (land stations) is a variation of abbreviated United States Model which includes all but the underlined portions of SM's and AW's, as follows:

iii Nddff VVww W PPPTT N_h C_L h_x C_M C_H

$T_dT_d$app 7 RRR$_t$S$_s$ 9 S_pS_ps$_p$s$_p$

Airways reports are substituted if synoptics are not available. Sea level pressure (PPP) is rounded off to the nearest whole millibar. See appendix 2 for land and ship report models.

3. DEADLINES:

Chart is plotted in several separate sections, determined by receipt of data on circuits at Suitland. Sections are then taped together and full chart is available to the analyst about 1 hour after data time, on the average.

Analysis Procedures

1. TIME AVAILABLE:

One supervising analyst and two assistant analysts work on the chart for about 20 minutes before it must be coded for teletypewriter. Another 5 minutes is then available for finalizing analysis before facsimile transmission deadline.

2. TOOLS AVAILABLE:

a. Previous 3 hourly North American analyses (corrected for later data over the Pacific and Atlantic at 00Z, 06Z, 12Z, and 18Z).

b. Analysis of 1000 to 500 mb thickness field at 00Z and 12Z.

c. 850 mb isotherm analysis at 00Z and 12Z.

d. Radar summary from MKC valid 15 minutes before map time.

e. Complete file of United States and Canadian hourly airways observations.

f. Gridded APT satellite photos provided by National Environmental Satellite Center.

Thickness and 850 mb isotherms are first available for use with 03Z and 15Z North American surface charts.

Philosophy of Analysis

Intent of analysis is to depict synoptic scale systems* of importance in weather forecasting. Therefore, smoothing of data is done to eliminate effects of errors and non-representativeness in observations and still retain details that are important to weather forecasting. (See page 2 of NAWAC Manual Part I.) Generally, surface fronts are located:

1. Along warm boundary of significant (e.g., where thermal shear >25 kt.) baroclinic zones shown on 1000-500 mb thickness and 850 mb isotherms, and along axis of maximum surface relative vorticity, i.e., along lines of strong low-level convergence, and

2. At the apex of significant (e.g., where thermal shear >25 kt.) thermal ridges on 1000-500 mb thickness chart, in case of occluded fronts.

3. Presence (or absence) of clouds and weather is also considered in locating and classifying the intensity of fronts. For more detailed discussion see:

REFERENCES:

1. STAFF A&FD, NAWAC Manual, Part I, pp. 5-7.

*On occasion, meso-scale systems shown on the Radar Analyses will be carried on the surface chart, especially if they persist for several 3-hourly charts.

Depiction and Coding

Fronts and instability (or squall) lines are depicted using WBAN Weather Analysis symbols (see appendix 2) further defined by 3-digit code figures with a bracket to the right. The code for type, intensity and characteristic is in accordance with "Front Group (3)" format of the Abridged U. S. Weather Analysis Code (January 1, 1949) shown in appendix 3. Dashed trough lines are identified by 6-digit "Pressure System Group (2)".

Isobars are depicted by solid lines at 4 mb intervals labeled by 2-digit numbers, tens and units of pressure in millibars. Occasionally, intermediate isobars at 2 mb intervals depicted as long-dashed lines, are used in areas of weak pressure gradient.

Pressure centers are indicated by "L" for low and "H" for high, labeled for central pressure by underlined 2-digit numbers in tens and units of pressure in millibars.

SA-2; SURFACE ANALYSIS

Plotted and analyzed by hand, Atlantic or Pacific Ocean section of Northern Hemisphere, at 1:20 million scale for 0000Z plus each six hours. Each 6-hourly chart is issued once as a Preliminary Analysis.

Plotting Procedures

1. NETWORKS:

   a. Only a limited network of stations is replotted over North American land areas since the complete network has already been plotted on the North American surface chart (SA-1).

   b. Over ocean areas, all available ship reports are plotted. Those reports which cannot be entered because of lack of space, are plotted along the border of the NMC plotted chart. A reference number (#1, #2, etc.) and the sea-level pressure (i.e., tens and units digits) are entered at the actual location of the report.

2. MODEL:

   Plotting model for land stations omits the RR, S_pS_p and s_ps_p groups. Ship report model is identical to that used on North American surface analysis, SA-1 (see appendix 2).

3. DEADLINES:

   For the preliminary version of the analysis, data are plotted up to approximately 1/2 hour before start of transmission of the analysis.

Analysis Procedures

1. TIME AVAILABLE:

   Analyst receives the first copy of the plotted chart about 2 hours after observation time. The deadline on the preliminary analysis is 20 minutes before transmission time.

2. TOOLS USED:

   a. Previous 6-hourly hemispheric or front half (see appendix 14) surface analyses.

   b. Hemispheric hand-analysis of 1000-500 mb thickness field at 00Z and 12Z.

   c. Norwegian Frontal Models (see appendix 4).

   d. Numerical Surface Analysis based on a 1+30 data cut-off at 00Z and 12Z.

e. Mosaics of gridded satellite pictures, digitized and actual, and annotated nephanalysis provided by National Environmental Satellite Center.

Philosophy of Analysis

Intent of the analysis is to portray the macro-structure of the polar front and its associated baroclinic zones around the hemisphere. The evolution of all cyclones and anticyclones along and on either side of the baroclinic zone are included in this portrayal. The arctic front is portrayed also when significant weather and temperature changes are associated with it.

The Norwegian Frontal Model (see appendix 4) is followed more faithfully over the oceans where data networks are sparse. (Over land areas, more frequent and regular data plus terrain-induced peculiarities often require deviations from the standard model).

Generally, surface fronts are located:

a. Along warm boundary of significant (e.g., where thermal shear >25 kt.) baroclinic zones shown by 1000-500 mb thickness and 850 mb isotherms, and along axis on maximum surface relative vorticity, i.e., along lines of strong low-level convergence; and

b. At the apex of significant (e.g., where thermal shear >25 kt.) thermal ridges on 1000-500 mb thickness chart, in case of occluded fronts.

c. Presence (or absence) of clouds and weather is also considered in locating and classifying the intensity of fronts. For more detailed discussion see:

REFERENCES:

1. STAFF A&FD, NAWAC Manual, Part I, pp. 5-7.

Depiction and Coding

As on the North American chart, fronts are depicted using WBAN analysis symbols (see appendix 2) and further explained by a 3-digit code figure according to the "Frontal Group (3)" format of the Abridged United States Weather Analysis Code (see appendix 3).

Isobars are depicted by solid lines at 4 mb intervals labeled by 2-digit numbers, tens and units of pressure in millibars. Occasionally, intermediate isobars at 2 mb intervals, dashed lines, are used in areas of weak pressure gradient.

Pressure centers are indicated by "L" for low and "H" for high, labeled for central pressure by underlined 2-digit numbers in tens and units of millibars.

SA-2A; SURFACE DATA

Plotted by hand, Atlantic Ocean section of the Northern Hemisphere, at 1:20 million scale at 0000Z plus each six hours.

Plotting Procedures

1. NETWORKS AND MODELS:

   Networks and models are the same as those described under charts SA-1 and SA-2.

2. AREA

   The area covered is a variation of that shown in appendix 15, excluding Europe but including the Gulf of Mexico, Central America, and northwestern South America.

3. DEADLINES:

   Data are plotted up to about one-half hour before transmission time.

SA-3; SURFACE ANALYSIS

Hand analyzed for front half (see appendix 14) of Northern Hemisphere. Transmitted with 1000-500 mb thickness analysis superimposed, without data for 0000Z and 1200Z at 1:30 million scale.

Plotting Procedures

Although no plotted data are shown on this chart, networks and models are identical to those for the Preliminary Surface Analysis, Atlantic and Pacific sections (with data), SA-2. Data are plotted up to approximately 1/2 hour before transmission time.

Analysis Procedures

Surface Analysis

Tools used and philosophy of analysis are identical to those for Preliminary Surface Analysis, Atlantic and Pacific sections (with data), SA-2 which is revised for data up to 3 1/2 hours after observation time. The analysis at 1:20 million scale is completed about one hour before transmission time and traced on reduced scale chart.

The 1000-500 mb thickness analysis

1. TIME AVAILABLE:

   This analysis is based on plotted data available up to 3 1/2 hours after observation time.

2. TOOLS AVAILABLE:

   a. Standard thickness frontal model (see appendix 4).

   b. 500 and 1000 mb analyses.

   c. 500 mb 12 hour prog.

3. PREPARATION:

   Analysis performed on 1:20 million scale is based on:

   a. Thermal winds computed by vector subtraction of geostrophically measured sea level winds from reported 500 mb (or 18,000 ft) winds.

   b. Thickness values determined by subtraction of reported or computed 1000 mb heights from reported 500 mb heights.

   c. Graphical subtraction of 1000 mb contours from 500 mb contours.

Over areas where data is plentiful, thickness isopleths are drawn to fit plotted thickness values and to approximate standard thickness-frontal model (see appendix 4). Over areas with little or no data, thickness contours are estimated first by graphically subtracting 1000 mb from 500 mb contour analyses. Adjustment of thickness pattern to conform to model shown in appendix 4 may result in modification of 1000 mb or 500 mb analysis, or both.

REFERENCES:

1. STAFF A&FD, NAWAC Manual, Part I, pp. 15-19.

Depiction and Coding

Depiction and coding of fronts is identical to that used on SA-1 and SA-2 surface analyses (see appendices 2 and 3).

Isobars are depicted by solid lines at 8 mb intervals labeled by 2-digit numbers, tens and units of pressure in millibars. Occasionally, intermediate isobars at 4 mb intervals, dashed lines, are used in areas of weak pressure gradient.

Pressure centers are indicated by "L" for low and "H" for high labeled for central pressure by underlined 2-digit numbers, tens and units of millibars.

Thickness isopleths are depicted by dotted lines at 60 meter intervals labeled in decameters.

SA-4; WEATHER DEPICTION ANALYSIS

Plotted and analyzed by hand for United States, southern Canada, and northern Mexico at 1:10 million scale for 0100Z plus each 3 hours.

Plotting Procedures

1. NETWORK:

No standard network is used. Chart is plotted from hourly airways observations. Air Force Base observations are used to fill in gaps in the network, especially during night hours when some civilian reporting stations do not operate.

2. MODEL:

The plotting model is an abbreviated version of the complete aviation report which includes a) significant weather, b) visibility c) total sky-cover, and d) ceiling height (see appendix 5). All ceiling heights (i.e., lowest cloud height with more than 5/10 coverage) are plotted. When total coverage is 5/10 or less, then height of lowest scattered layer is plotted. Visibilities over 6 miles are not plotted.

3. DEADLINES:

The base-chart is divided near the mid-continent so that two chartists may plot simultaneously from different Service A circuit listings. The plotting deadline is 45 minutes after the synoptic hour. The plotted chart is then reproduced for internal use which requires 5 minutes.

Analysis Procedures

1. TIME AVAILABLE:

From 15 to 20 minutes are available for analysis of this chart. Actual analysis time varies depending on the amount and complexity of the clouds and visibility to be depicted.

2. TOOLS AVAILABLE:

a. Previous weather depiction analyses.

b. Latest surface analysis, usually for the previous hour.

Philosophy of Analysis

This analysis portrays the synoptic-scale structure of ceiling and visibility in two operational categories, vis:

1. Ceiling less than 1000 feet and/or visibility less than 3 miles, solid lines.

2. Ceiling 1000 to 5000 feet and visibility 3 miles or more, scalloped lines.

The analysis of these two operational categories is shown as continuous within the network of reports plotted on the chart. Smaller-scale fluctuations in category due to variations in local terrain, etc., are not intended to be portrayed on this chart. The chart is designed primarily as a briefing tool to alert aviation interests to the location of critical or near-critical operational minimums at terminals in the United States and surrounding land areas.

SA-5; RADAR ANALYSIS (ADUS) MKC

Contiguous United States east of Plateau, 1:10 million scale for 0245Z plus each 3 hours and selected 5-minute sections of United States for 0445Z, 0745Z, 1945Z, 2145Z and 2245Z.

Plotting Procedures

1. NETWORKS:

All WSR-57 reports, plus 12 Air Force CPS-9 radar reports and selected SP-1, WSR-1, 3, and 4 radar reports which comprise the basic network are plotted routinely as they are received. Additional WSR-1 and 3 reports are plotted whenever they are pertinent. Salt Lake City ESSA-FAA ARTC radar data are entered on the 1445Z and 2045Z charts. (See appendices 6, 7) When convective activity is widespread, reports are plotted by two technicians.

2. MODEL:

Reports are plotted each hour, using a slightly modified version of the standard facsimile radar chart nomenclature.

3. DEADLINES:

The raw data or the SD's are taken at H+30 (30 minutes past the hour). Receipt of reports (SD's) begins at H+45 which are plotted until all received or until H+80 (maximum of 35 minutes of plotting time).

Analysis Procedures

1. TIME AVAILABLE:

The time for analysis varies from 3 to 10 minutes (H+90 total elapsed time) depending on the weather situation. The next step is to code the analysis for transmission on Service A and RAWARC. Two men are involved in this 5 minute step; the analyst dictates the coded information and another man types it. Echo outlines are traced from the master plotting chart, using light reduction equipment. Adjacent smaller areas of similar echo are sometimes grouped as a single area if this should not result in a change of category (i.e., from broken to scattered). Thus, the analysis (including preparation of the SD-1 word summary) is accomplished between H+80 and chart filing time at approximately H+110 (about 65 minutes after time of observations).

2. TOOLS USED:

a. Previous hourly RADU plots of radar activity are used for continuity.

b. Current standard synoptic surface and upper air analyses (plus hourly sectional surface analyses for areas of intense activity).

c. Hourly sequences for point verification of precipitation, location, type, and intensity.

d. Current status check of all radars plus intelligence of what type radar used to report echoes.

Philosophy of Analysis

The intent of the radar analysis is to depict the mesoscale and general macroscale distribution of precipitation patterns (including layers of "wet" clouds with which surface precipitation may or may not be occurring). Since the radar coverage is frequently overlapping and individual radars are observing the echo from different angles and ranges (therefore heights), the analysis must include an intelligent interpretation of the overlapping data. A further consideration in analysis is that echoes may be reported by high powered 10 cm radars (WSR-57), high powered 3 cm radars (CPS-9) or low powered 10 cm radars (WSR-1 or 3). Each of these have quite different observational capabilities which must be considered in the final analysis.

REFERENCES:

1. Foster, Jr., H. E., "Methods Used in the Production of the Radar Summary Facsimile Chart", Notes to Forecasters ESSA, Weather Bureau, May 1965.

Depiction

Analysis of radar echoes is depicted in the format of appendix 8, "Explanation of Radar Summary Chart".

In addition, the radar type at each site and the areas beyond normal operational range of the radars are identified. A legend of radar types is included on each transmitted chart. Areas where there is no radar coverage due to the absence of radars or beyond 75 nautical miles from WSR 1, 3, and 4, and 125 nautical miles from WSR 57, CPS 9, SP 1, FPS 41, and FAA radars are stippled as a permanent feature of the base map. When echoes are observed beyond the normal operational range of the radars, they are superimposed on the stippling.

Tornado Watch areas are outlined by dashed lines and Aviation Severe Weather Bulletin areas by dotted lines; "boxes" are labeled by watch number. Consecutively numbered suffices are added if there is more than one box in the weather watch. The weather warning number and valid ending time (Z) corresponding to each box number are indicated in the lower left portion of the chart in the format:

WW NR _____

VALID TIL ____Z

SA-6; HNL SURFACE ANALYSIS

Plotted and analyzed by hand for the tropical Pacific area (see appendix 45-Area I) on a 1:20 million scale Mercator chart for 0600Z and 1800Z.

Tools Available

1. Previous six hourly analysis.
2. 1000-500 mb and 1000-250 mb thickness fields.
3. At higher latitudes, surface, thickness and upper air charts from NMC.
4. Local APT pictures (morning) from the West Coast to Japan. (The Western picture strip is relayed from WBAS, Wake Island.)
5. NESC cloud mosaics of the tropical Pacific area in the evening.
6. Typhoon/hurricane advisories.
7. Pilot reports of significant weather occurrences.

Philosophy of Analysis

The philosophy is similar to that of NMC in higher latitudes except the isobaric analysis is considered to represent the tropical wind field poorly.

Depiction

Isobars are depicted by solid lines at 4 mb intervals and are labeled by 2-digit numbers, tens and units in millibars. Occasionally intermediate isobars at 2 mb intervals are entered as dashed lines.

Pressure centers are indicated by "L" for low and "H" for high. Fronts are depicted using WBAN Weather Analysis symbols (see appendix 2).

Plotted data are deleted from the chart to reduce blurring during radio facsimile transmission.

SA-7; SURFACE ANALYSIS - MIA

Plotted and analyzed by hand for 0000Z plus each 6 hours. Area bounded by 45 N latitude and the Equator; 125 W and 10 W longitude, 1:10,000,000 scale, modified Mercator projection as shown in appendix 52.

Plotting Procedures

1. NETWORKS:

Over the continental U. S., only selected land stations south of 36 N are plotted (see appendix 53). Elsewhere as many land stations are plotted as can be entered on the chart without undue crowding. Nearly all ship reports are plotted, and where crowding occurs the additional reports are plotted off position in sparse data areas. Unplotted ship reports are given to the analyst to scan. The reports from Africa and South America as well as ship reports that are not available to the analyst at chart deadline, are entered as late data.

2. MODEL:

Plotting model (see appendix 2) is a variation of abbreviated United States model which includes all but the underlined portions of SM's and AW's, as follows:

$$iii \quad Nddff \quad \underline{VV}\underline{ww}\underline{W} \quad PPPTT \quad \underline{N_h}C_L\underline{h_x}C_MC_H \quad T_dT_dapp \quad 7RRR_tS_s$$

$$9S_pS_ps_ps_p \quad 1d_wd_wP_wH_w$$

Airways reports are substituted if synoptics are not available. Sea level pressure (PPP) is rounded off to the nearest whole millibar. 850 mb heights are plotted instead of sea level pressure for certain stations in Africa and South America at high elevations. Sea water temperatures are plotted for United States stations 699, 211, 231, 202, and 251, and for selected ships.

3. DEADLINES:

The entire chart is plotted by one chartist. On the 0000Z and 1200Z charts, analysis begins 4 1/2 hours after data time. Analysis of the 0600Z and 1800Z charts begins two hours after data time.

Analysis Procedures

1. TIME AVAILABLE:

One analyst prepares the initial analysis of each chart. Facsimile transmission deadlines allow a period of two hours for the analysis of each 0000Z and 1200Z chart - 1 1/2 hours for the

for the 1800Z chart and only one hour for the 0600Z chart. After each chart has been transmitted, late data is plotted and the analysis is reworked -- where necessary -- to provide continuity for analysis of the succeeding chart.

On the 0000Z and 1200Z analyses (see appendix 54), a brief typewritten script is added to the chart to provide comments on or explanation of features not evident from the analyses themselves; or, more frequently, to identify features or trends observed by weather satellites.

2. TOOLS AVAILABLE:

a. The NMC surface analysis for North America, and the North Atlantic Ocean.

b. Previous 6 hourly surface analyses.

c. T.O.E. (Top of Ekman Layer) wind analyses at 0000Z and 1200Z.

d. Six hourly pibals for selected levels.

e. Gradient level pibals entered directly on the chart in non-reproducing light blue pencil.

f. APT satellite pictures as received at MIA plus a far eastern pass received at San Juan, P. R., and relayed to MIA.

g. Digital photo mosaic received by facsimile from NESC in time for use on 0000Z analysis.

h. Nephanalyses on the same scale and projection for the area north of 30 S, and on a polar stereographic projection for the area south of 30 S.

i. Mean monthly charts of surface wind, pressure, and precipitation.

j. Radar reports - domestic and foreign.

k. Aircraft reconnaissance reports.

Philosophy of Analysis

The intent of the analysis is to portray synoptic scale systems of importance to weather depiction and forecasting. Therefore, smoothing of data is done to eliminate effects of errors and non-representativeness in observations. Wherever the data permit (as when an unusual concentration of ships occurs; aircraft reconnaissance, radar, or satellite observations are available, etc.) meso-scale systems are also portrayed. In general:

1. Surface positions of fronts over the northern portions of the chart are copied from and/or blended into the NMC analyses for the same areas.

2. Surface positions of fronts over the southern portions of the chart are derived largely from the NMC nephanalyses, from what surface reports are available, and from coded analyses sent by the meteorological services of countries in Africa and South America.

3. Surface positions of fronts elsewhere are determined by standard methods except that no thickness analysis is done.

4. Tropical storms, hurricanes, and occasionally other tropical disturbances such as easterly waves, are frequently well depicted by the pressure analysis. However, the majority of weaker systems near the equatorial latitudes, and in particular the daily position of the intertropical convergence zone (or zones), are best shown by the streamline analysis on the T.O.E. chart.

   a. Where insufficient data are available to define the systems, an effort is made to depict a flow pattern in the Atlantic similar to that shown in appendix 55.

   b. Where insufficient data are available to define the pressure field, the pressure analysis is made to follow continuity first and then gradually to approach a normal pattern for the season.

5. Heavy reliance is placed on the observations received from the weather satellites.

Depiction and Coding

Fronts, troughs, ridges, highs, and lows are depicted with standard NMC Weather Analysis Symbols (see appendix 2).

Easterly waves, shear lines, reflected troughs, and the ITC are depicted by means of a heavy dashed line with the appropriate label stamped along it.

Tropical disturbances are identified by the stamped symbol "T_D". These are defined as synoptic scale areas of disturbed weather persisting for 24 hours or longer but lacking the organized circulation required for classification as depressions.

Tropical depressions are identified by the stamped symbol "T_C" with subscript numbers SSNNDD, where SS is day of month the depression is named (XX for unnamed depressions), NN is the seasonal sequential tropical cyclone number assigned to the depression, and DD is the number of GMT calendar days the depression is carried on the chart.

Tropical storms are identified by the symbol "T_S" and a printed name with subscript numbers SSNNDD as above.

Hurricanes are identified by the symbol "S" with printed name and subscript numbers as above.

SA-8; SURFACE ANALYSIS (TOP OF EKMAN LAYER) MIA

Plotted and analyzed by hand at 0000Z and 1200Z for the area bounded by 35 N and 40 S latitude and 150 W and 20 E longitude on a 1:20 million scale modified Mercator projection (see appendix 52).

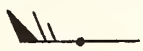
Plotting Procedures

1. NETWORKS:

   All surface ship winds and upper winds at 3,000 feet are used. Land stations are used over South America and Africa south of 10 N latitude. Cloud analyses from satellite photographs are also entered with the primary emphasis on major convective cloud systems.

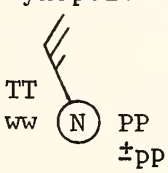
2. MODEL:

   a. PIBAL and RAWIN data -- the standard NMC model is used except that the wind shaft is extended beyond the station circle to distinguish those types of data from the surface wind data plotted on the same chart:

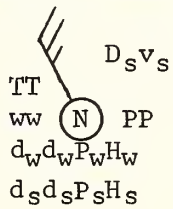
   

   b. Surface synoptic data -- an abbreviated NMC model is used:

   Land

   Ships

   Note: Over areas also covered by the sea level chart, only wind data (surface and 3,000 ft) are plotted on the TOE chart.

   c. Direction of motion of low clouds -- plotted as a 3/8" arrow above the station circle:

3. DEADLINES:

   Analysis of this chart begins four hours after data time. Data received after that time are plotted in red ink, but this distinction is not discernible on the transmitted copy.

Analysis Procedures

1. PREPARATION:

   This chart is analyzed in close coordination with the sea level chart and is designed to give a representative flow pattern and related cloudiness for the low troposphere. A pattern of streamlines is constructed with due attention to cloud organization, pressure pattern, and continuity.

2. TOOLS AVAILABLE:

   a. NMC surface analysis for North America and the North Pacific Ocean.

   b. Previous 6 hourly surface analyses.

   c. Previous TOE layer analysis.

   d. Six-hourly pibals for selected levels.

   e. APT satellite pictures as received at MIA plus a far eastern pass received at San Juan, P. R., and relayed to MIA.

   f. Digital photo mosaics.

   g. Nephanalyses.

   h. Mean monthly charts of surface wind, pressure, and precipitation.

   i. Radar reports - domestic and foreign.

   j. Aircraft reconnaissance reports.

3. TIME AVAILABLE:

   One and a half to two hours are allotted for the analysis of this chart.

Philosphy of Analysis

The sea level chart and the TOE chart complement one another. If the information available could be satisfactorily analyzed on a single chart, that would be preferable. This is impractical, so the sea level chart is drawn to provide a larger scale presentation of pressure and frontal patterns over a limited area, and the TOE chart to provide a low latitude streamflow and nephanalysis in both hemispheres. The TOE chart is analyzed on the same base map as that used for the upper-air analyses to simplify procedures for achieving vertical consistency through all levels of analysis.

The cloud analysis depicted on this chart aids in establishing the position of the ITC, other lines of convergence, and areas of disturbed weather. Use is also made of an unpublished study which indicates that the surface wind over the oceans in equatorial latitudes is most often nearly parallel to the orientation of cumulus cloud lines as viewed by weather satellites.

REFERENCE:

1. Gaby, Donald C., "Cumulus Cloud Lines Vs. Surface Wind in Equatorial Latitudes", (Manuscript submitted for Publication), Tropical Meteorological Center, ESSA, Miami, Florida, September 1966.

Depiction and Coding

1. Wind flow is depicted by streamlines and isotachs.

2. In the satellite photographs, areas covered, or mostly covered, by bright clouds are outlined in a heavy solid line and shaded in lightly with a screen mesh underlay.

3. Circulation centers are identified by stamped symbol as follows:

   C.....Cyclone

   A.....Anticyclone

   A_t....Thermal anticyclone, defined as smaller scale anticyclonic circulations found in the upper troposphere, formed essentially through convective release of latent heat and accompanied by cloud or rainy conditions.

   E.....Equatorial circulation centers which can not readily be classified as cyclones of either hemisphere.

4. Fronts are depicted by means of the standard pipped lines. (See appendix 2.)

5. Troughs, shear lines, easterly waves, and the ITC are shown as heavy broken lines with appropriate titles stamped along them.

UA-1; UPPER AIR ANALYSIS

For major portion of North America and contiguous areas of the eastern Pacific and western Atlantic Oceans (FAX Section 1 as shown in appendix 13)[1] on a 1:20 million scale for 0000Z and 1200Z. The analyses are:

1. 850 and 500 mb: hand plotted and analyzed.

2. 700, 300, and 200 mb: computer analyzed with analyses and data reproduced by Digifax process.

A. 850 mb and 500 mb Charts

Plotting Procedures

1. NETWORKS:

All available radiosonde, rawinsonde, pibal, and weather reconnaissance reports are plotted by hand. Over ocean areas, available AIREP and reconnaissance reports are plotted according to the criteria listed in paragraph 2 of appendix 9. In actual practice, transmission of the 850 mb and 500 mb analyses within 2 1/2 hours of observation time restricts plotting of AIREP data on these charts.

2. MODELS:

a. Station model used to plot radiosonde, rawinsonde and pibal reports is shown in paragraph 1 of appendix 9. On the 850 mb chart, where observing station is above the 850 mb surface, computed temperatures[2] are plotted with a bracket to the right.

b. The station models used to plot AIREP and reconnaissance reports are described in appendix 9, paragraphs 2 and 3.

3. DEADLINES:

Deadlines for entering all data on hand-plotted and analyzed 850 and 500 mb charts are about 1 1/2 hours after observation time.

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[1] A larger section (i.e., Ia) including all of Alaska is used for 500 mb and a smaller section for 850 mb analyses.

[2] Temperatures are computed by assuming standard atmosphere lapse rates in winter and almost dry adiabatic lapse rates in summer between 850 mb and 775 mb. Estimates are made as follows: 775 mb plus 5° C in winter and plus 7° C in summer; at Ely, Nevada: 725 mb temperature plus 10° C all seasons.

Analysis Procedures

850 mb Chart

1. TIME AVAILABLE:

   One man completes the analysis in about 3/4 hour by direct analysis of the data.

2. TOOLS AVAILABLE:

   a. Surface analysis for the same synoptic hour.

   b. Previous 850 mb analysis, or "continuity".

   c. Hand recomputations of the 850 mb temperatures over western United States. (See page 21 of NAWAC Manual, Part I). Heights at 850 mb are also available from the 12Z airway reports to use in the analysis over the intermountain area of the western United States.

      The frontal intersections at 850 mb are located along the warm boundaries of baroclinic zones (as revealed by the 850 mb isotherms) where relative (cyclonic) vorticity is a maximum, in other words, along lines of strong low level convergence. Reasonable frontal slopes from 850 mb to the surface are also used to interpolate fronts between upper-air observations.

500 mb Chart

1. TIME AVAILABLE:

   One supervising analyst and two assistant analysts complete the analysis in about 1/2 hour (1 1/2 man hours) by direct analysis of the data.

2. TOOLS AVAILABLE:

   a. Location of surface fronts and centers.

   b. Previous 500 mb analyses, or "continuity".

   c. The latest 12-hour NWP prognosis of the 500 mb flow, based on a computer analysis made from a data cut-off time 8 hours after the previous set of observations. Generally, the 12-hour prognosis is weighted most heavily over ocean areas and Mexico.

Depiction

Fronts (on the 850 mb analysis) are depicted using WBAN analysis symbols identical to those used on surface analyses (see appendix 2).

Contours are depicted by solid lines at 60 meter intervals labeled by 3-digit numbers in decameters and also in D-values, the departure of the height in feet from the height of a standard atmosphere at the pressure surface (1457 meters at 850 mb and 5580 meters at 500 mb). Occasionally, intermediate contours drawn as long-dashed lines at 30 meter intervals are used to delineate patterns in areas of weak gradient.

Circulation centers are identified by the conventional "L" for lows and "H" for highs.

Isotherms are drawn as short dashed lines at 5° C intervals, so labeled. These also represent lines of equal potential temperature.

B. 700, 300, and 200 mb Charts

Computer Analysis Procedures

1. Automatic Data Processing

The computer analysis proceeds as a separate operation from the hand-plotted analyses already discussed. The analyses which are done in the computer use data which are fed directly from national and international teletype circuits, through a communications computer (IBM 360 System), to the main NMC computer (IBM 7094). Then an ADP program decodes, checks, recomputes and lists all available radiosonde, rawinsonde, pibal, reconnaissance AIREP, and any bogus* reports. A brief description of the ADP program can be found in:

REFERENCES:

1. Burnett, F. W., "The Role of the Computer in Meteorology", Weatherwise, Vol. 18, No. 5, October 1965.

Civilian AIREP reports are edited and coded for use in ADP at five Weather Bureau field offices (see appendix 10). Approximately 75 military AIREPS are also made available to NMC by each data cut-off time from the USAF Computerized Flight Planning Section at Suitland. These reports are primarily over the Atlantic and Pacific Oceans, although a few North American reports are available.

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*Bogus reports are any height, wind or temperature data that have been computed, extrapolated, or otherwise manufactured by a monitoring analyst and inserted by hand.

Deadlines for data collection for the computer analyses are as follows:

Computer Data

Chart	Deadline (after 00Z or 12Z)
700 mb	1 1/2 hours
300 mb	3 hours and 25 minutes
200 mb	3 hours and 25 minutes

2. Analysis Procedure

Details of NMC's complex and ever-changing computer analysis procedures will not be given here. The most recent references on this subject are:

REFERENCES:

1. Gustafson, A. F., and McDonell, J. E., "The Derivation of First-guess Fields for Objective Analysis, 1000 mb to 500 mb", NMC Technical Memo #31; or

2. Kulawiec, M. H., "The New Machine Analysis" Notes to Forecasters, May 1965.

The computer analysis involves three procedures:

a. Obtaining the best "first guess" of values of parameters (height, temperature) at grid points from a short range prognosis (12 hours) or from extrapolation by statistical regression equations from values of parameters at grid points already determined by analyses at other levels. The references listed above detail the methods of obtaining guess fields at 1000, 850, 700, and 500 mb. Appendix 12 outlines the present methods for 300, 200, and 100 mb.

b. Adjusting these guess values by a weighted average of the new observational data available in an influence area surrounding each grid point. The size of the influence area is controlled by the amount of data available. Over North America this influence area averages about 400 nautical miles in radius. Over ocean areas, where observations are much more sparse, a much larger (up to 1000 nautical miles in radius) influence area is searched before enough observational data for a new determination of grid point values are obtained. Often, over the Pacific Ocean especially, the guess field becomes the final data field when no observations are available at any level.

c. The grid point data is run through a data processor on the IBM 7094 computer which determines a closely spaced set of x, y-coordinates for the height contours and isotherms (also isotachs) of the analysis by quadratic interpolation from the grid point values. The coordinates may be traced out by the Curve Follower or Digifax process to give the finished analysis of the grid point data.

Geostrophic winds are determined at each grid point from the final height data for a "first guess" field. The grid point winds are adjusted for actual wind observations using the same technique as was used for the height and temperature fields. Over dense-data areas, the observed wind velocities determine the grid point values. In sparse-data areas the grid point wind velocities are based primarily on the geostrophic wind derived from the height differences between grid points.

3. Philosophy of Analysis

Computer analyses are made from data derived at a network of grid points spaced about 180 nautical miles apart (see appendix 11). Systems with wave lengths(trough-to-trough distance) less than 200 nautical miles will not be evident on these analyses. Furthermore, smoothing during the computer analysis generally eliminates most systems with wave lengthsless than 400 nautical miles.

D e r i v a t i o n

The analyses are produced by the Digifax process as follows:

1. The data processor output of x, y-coordinates for points on the lines representing each isopleth also contains the locations of station circles and sets of numbers for the data at each observation point.

2. The output is fed into a cathode ray tube activating an electron beam which traces out the x, y-coordinates of the isopleths, the station circles and the observational data.

3. The electron beam impinges on a phosphor target about 40 mm square on the face of the CRT causing an image of the isopleths and data to appear momentarily.

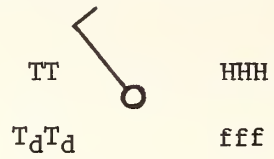
4. The image is reflected by a mirror into a camera exposing a film frame about 30 mm square. At the same time, an electronic flash through a slide sends an image of the appropriate geographical background through the mirror on to the same film frame.

5. The microfilm is processed and mounted on an aperture punch card with information as to type of chart, date and time prepunched and printed on the card.

6. The microfilm is enlarged to hard copy suitable for facsimile transmission.

Depiction

Observational data are depicted as follows:



The wind direction is indicated by a shaft with a short barb at right angles plotted to 36 points.

The wind velocity, fff, is given by a 3-digit number in knots.

The height, HHH, is in meters with thousands digit omitted at 700 mb; in decameters at 300 mb; and in decameters with ten-thousands digit omitted at 200 mb.

The temperature, TT, and dewpoint T_dT_d, are in degrees Celsius. In addition temperature-dewpoint spread of 5° or less is indicated by filling in of the station circle on 700 mb analysis only.

Because of the necessity of allowing for space to plot the observational data with no overlap, only about 60% of the available observations may be plotted. These are selected from a listing of priority stations which are plotted routinely, unless all or a portion of the data is missing when a nearby station is substituted. However, the analysis is based on all of the available observations. There is no backup procedure for hand plotting of data if the Digifax program fails.

Digifax charts are limited to 2 sets of isopleths. Height contours are depicted as solid lines on all charts. They are hand labeled by 3-digit numbers in decameters (except with ten-thousands digit omitted at 200 mb). In addition, base contours, the heights of a standard atmosphere at the particular constant pressure surface, are indicated by short-dashed lines for reference values. These values are 306 decameters with contour intervals of 60 meters at 700 mb; and 924 decameters at 300 mb and 1188 decameters at 200 mb with contour intervals of 120 meters at both these levels.

Circulation centers are identified by + with the conventional "L" for lows and "H" for highs; labeled by 3-digit numbers, in meters with thousands digit omitted at 700 mb and in decameters at 300 and 200 mb (ten-thousands digit omitted at 200 mb).

Dashed lines depict isotherms at 5° intervals hand labeled in degrees Celsius on 700 mb analysis; and isotachs at 20 knot intervals hand labeled in knots on 300 and 200 mb charts.

Jet axes are not explicitly indicated; their positions must be inferred from the isotach patterns and plotted wind velocities.

There is no backup procedure for plotting data when the Digifax program fails. At these times, the Curve Follower output of analyzed contours, isotherms and isotachs will be transmitted without observational data.

Addendum:

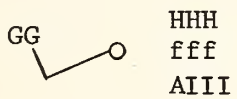
Production of 300 mb and 200 mb analyses by the Facsimile Group Converter in lieu of Digifax was begun November 7, 1967. Depiction by the new system is as follows:

1. Almost all land and ship reports and also aircraft reports can be plotted. When reports are so close together that printed data overlaps, one is omitted.

2. The charts are limited to two sets of isopleths also. Contours are drawn as solid lines at 120 meter intervals with no labeling. The 9480 and 9000 meter contours at 300 mb and the 12240 and 11760 meter contours at 200 mb are drawn as heavier solid lines. Isotachs are drawn as dashed lines at 20 knot intervals with no labeling. Values must be inferred from plotted velocities.

3. Highs are indicated as + and lows as - with labels in decameters printed in white within a black rectangle.

4. The plotting model for aircraft reports plotted over ocean areas is:



The wind direction is indicated by a shaft with a short barb at right angles plotted to 36 points.

The wind velocity, fff, is given by a 3-digit number in knots.

The altitude of the aircraft, HHH, is plotted in tens of feet with initial digit omitted (500 = 35,000 ft.).

The identification of the aircraft report, AIII, refers to the ADP listing.

UA-2; UPPER AIR ANALYSIS

Computer analyzed without plotted data for North American side of Northern Hemisphere (Front Half Section)[1] on a 1:30 million scale chart at 0000Z and 1200Z. These analyses are:

a. 500 mb analysis, including contours and isotherms.

b. 300 mb analysis including contours and isotachs, with selected Pacific and Atlantic data plotted by hand.

c. Initial 500 mb vorticity analysis, including isopleths of absolute vorticity.

Computer Procedures: ADP

These analyses are based on Automatic Data Processing (ADP) which begins at 3+25[2] hours after observation time when data, available in the storage facility of the NMC Communications Computer (IBM 360 System), are fed into the main NMC computer (IBM 7094). Then the ADP program decodes, makes hydrostatic checks, recomputes and lists all available radiosonde, rawinsonde, pibal, reconnaissance and AIREP reports. Civilian AIREP reports, edited and coded at five Weather Bureau field offices are occasionally available for these analyses (see appendix 10). Approximately 75 military AIREP's primarily over the ocean areas are available to NMC by the data cut-off time from the USAF Computerized Flight Planning Section at Suitland. A brief description of the ADP program can be found in:

REFERENCE:

1. Burnett, F. W., "The Role of the Computer in Meteorology", Weatherwise, Vol. 18, No. 5, October 1965.

Computer Analysis Procedures

Details of NMC's complex and ever-changing computer analysis procedures will not be included here. The most recent references available on this subject are:

REFERENCES:

1. Gustafson, A. F., and McDonell, J. E., "The Derivation of First Guess Fields for Objective Analyses, 1000 mb to 500 mb", NMC Tech Memo #31, or

2. Kulawiec, M. H., "The New Machine Analysis", Notes to Forecasters, May 1965.

[1] See appendix 14.

[2] By NMC convention, the time is listed as number of hours plus number of minutes after observation time.

Philosophy of Analysis

The most important points to understand when using computer analyses are:

1. Computer analyses are made from data derived at a network of grid points spaced about 180 nautical miles apart (see appendix 11). The positions of isopleths drawn by the Curve Follower are interpolated from values at points on this fixed grid. Systems with a wavelength (e.g., troughs, lows) less than 200 nautical miles in extent will not show up on these analyses. Furthermore, smoothing during the computer analysis eliminates "wiggles" or systems smaller than 400 nautical miles in extent.

2. The computer analysis involves two main procedures:

   a. Obtaining the best guess of values of parameters (height, temperature) at grid points from a short-range prognosis or by extrapolation with statistical regression equations from values of parameters already analyzed at other levels. The two references listed above, detail the method of obtaining the 500 mb guess field. The 300 mb guess is obtained as shown in appendix 12.

   b. Adjusting these guess values by a weighted average of the new data available in an influence area surrounding each grid point. The size of the influence area is controlled by the amount of data available. Over the United States, this influence area averages about 400 nautical miles in radius. Over ocean areas, where observations are few and far between, a much larger (up to 1000 miles) influence area is searched before enough data for a new analysis is obtained. Often, over the Pacific ocean, the guess field becomes the new analysis when no new data are available at any level.

Computation of Parameters

1. Contours and isotherms

These are computed using the ADP (automatic data processing) and analysis procedures described in the preceding paragraphs.

2. Isotachs

On the 300 mb analysis, the isotachs are based on a wind analysis using geostrophic wind as a first-guess and adjusting this by the wind observations. Over dense data areas, the new data determine the isotachs by the same method and within the same scale limitations already listed for contour and isotherm analyses.

Over sparse-data areas, the isotachs are based primarily on the geostrophic wind derived from the contour spacing.

3. Absolute vorticity

The absolute vorticity (η) consists of the relative vorticity plus the Coriolis Parameter, or earth's vorticity, viz:

$$\eta = \zeta + f$$

It has the dimensions of $sec^{-1} \times 10^{-5}$ on the NMC charts. The value of f varies from 8×10^{-5} along the Gulf of Mexico coast to 12×10^{-5} in southern Canada in the units used on the charts. Therefore, in mid United States, an absolute vorticity of 10×10^{-5} sec^{-1} is close to the local value of the Coriolis Parameter (f) with a near zero relative vorticity.

Absolute vorticity is determined and analyzed as follows:

a. Height fields at seven sigma surfaces (see chart UP-2 and appendix 39) are computed from height and temperature fields at nine analyzed constant pressure surfaces and the tropopause.

b. Heights at the sigma surfaces are unsmoothed to overcome truncation errors which result from the multi-step procedure used to compute the relative vorticity. The unsmoothing has the effect of amplifying the winds computed from the heights.

c. Heights on the sigma surfaces are averaged to give the mean heights in the six sigma layers between (appendix 39). The balance equation is solved to give a mean stream function field in these layers.

REFERENCE:

1. Shuman, F. G., "Numerical methods in weather prediction: I. The balance equation," Monthly Weather Review, Volume 85, October 1957 pp 329-332.

d. Mean u- and v-components for these layers are computed from stream function fields by equations:

$$u = \frac{\partial \Psi}{\partial y} \qquad v = -\frac{\partial \Psi}{\partial x}$$

where Ψ is the stream function

e. u- and v-components at 500 mb are interpolated assuming a linear variation with a function of pressure π[1].

f. Absolute vorticity at 500 mb is computed by

$$\eta = \zeta + f = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} + f$$

at each grid point.

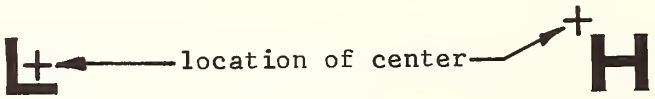
Curve Follower

A special computer program determines the x- and y-coordinates of location points 1/8" apart on the map scale along standard isopleths of the parameters by quadratic interpolation of the grid point values. The Curve Follower traces out the location points to draw the various isopleths.

Depiction

Contours are depicted by solid lines at 1) 60 meter intervals on 500 mb and 2) 120 meter intervals on 300 mb charts. Contours are hand-labeled by 3-digit numbers in decameters.

Circulation centers are indicated by "L" for lows and "H" for highs. "H" and "L" symbols drawn by the Curve Follower always bear the same relation to the location of the actual center, as shown here:



Short-dashed lines depict 1) isotherms at intervals of 5°C so labeled on 500 mb charts and 2) isotachs at intervals of 20 kt up to 160 kts and intervals of 40 kt above 160 kt on 300 mb charts labeled in knots.

Isopleths of absolute vorticity are depicted by solid lines at intervals of 2×10^{-5} sec^{-1} hand-labeled as 2, 4, 6, etc. Centers of maximum and minimum vorticity may be marked by + with value indicated by the multiple of 10^{-6} sec^{-1}.

---

[1] π is the ratio of absolute temperature to potential temperature:

$$\pi = \frac{T}{\theta} = \left(\frac{p}{1000}\right)^{\frac{R}{c_p}} = \left(\frac{p}{1000}\right)^{2/7}$$

UA-3; UPPER-AIR ANALYSIS

Hand-plotted and computer analyzed, Pacific and Atlantic Sections of Northern Hemisphere (see appendix 15) on a 1:20 million scale chart for 0000Z and 1200Z. Charts in this series are:

1. 700 mb contours and isotherms, Atlantic Section without data, Pacific Section with data.

2. 500 mb contours and isotherms, Atlantic and Pacific Sections with data. (A preliminary and operational edition of this chart are sent).

3. 300 mb contours and isotachs, Atlantic and Pacific Sections with data.

4. 200 mb contours and isotachs, Atlantic Section without data, Pacific Section with data.

Plotting Procedures

700 mb chart

1. NETWORKS:

   On Pacific Section only, all island, OSV[1] and moving ship radiosonde and rawinsonde reports plus coastal North American, coastal Asian and all Alaskan radiosonde and rawinsonde reports available by 1/2 hours before transmission time are plotted. No AIREP data are plotted. Data are plotted on a 1:30 million base chart.

2. MODEL:

   The plotting model (see appendix 9) follows the abbreviated WMO model for upper air data.

3. DEADLINES:

   Plotting of data on the 1:30 million base chart stops at 1/2 hour before transmission time. The chart is then transferred to the Curve Follower which draws the computer analysis. The completed chart is then enlarged photographically to a 1:20 million scale for transmission. A check-list of key ocean observations used in the computer analysis appears on each chart.

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[1]Ocean Station Vessel

500 mb chart

1. NETWORKS:

On the NMC hemispheric 1:20 million base chart are plotted all island, OSV and moving ship, and North American radiosonde and rawinsonde reports. Over Europe and Asia, the reports are plotted for a network shown by circled stations in appendix 15.

2. MODEL:

The plotting models used for radiosonde, reconnaissance and the criteria and model used for AIREP reports are shown in appendix 9. The radiosonde plotting model follows the abbreviated WMO model for upper air data.

3. DEADLINES:

Data plotted on the NMC hemispheric 500 mb 1:20 million base chart are reproduced at 3 1/2 hours after observation time for the PRELIM analysis (1+30) and at about 5 hours after observation time for the OPERATIONAL (3+25) analysis on a 1:30 million scale. The analyses are drawn by the Curve Follower and photoenlarged to 1:20 million for transmission. A checklist of key ocean observations used in the computer analysis appears on each chart.

300 mb chart

1. NETWORKS:

On the Pacific Section only are plotted all island, OSV, and moving ship plus coastal North American, coastal Asian, and all Alaskan radiosonde and rawinsonde reports across the Pacific to 120° E longitude. Over Asia and Europe, the network shown in appendix 15 is used.

2. MODEL:

The plotting models used for radiosonde, reconnaissance, and the criteria and model used for AIREP reports are shown in appendix 9. The radiosonde plotting model follows the abbreviated WMO model for upper air data.

3. DEADLINES:

All observations available by 1/2 hour before transmission time are plotted. Data are plotted on the 1:30 million base chart on which the computer analysis is drawn by the Curve Follower. This chart is enlarged photographically to a 1:20 million scale for transmission. A checklist of key ocean observations used in the computer analysis appears on each chart.

200 mb chart

1. NETWORKS:

   On Pacific Section only, all island, OSV and moving ship, plus coastal North American, Coastal Asian, and all Alaskan radiosonde and rawinsonde reports are plotted. No AIREP or reconnaissance data are plotted.

2. MODEL:

   The plotting models used for radiosonde, reconnaissance and the criteria and model used for AIREP reports are shown in appendix 9. The radiosonde plotting model follows the abbreviated WMO model for upper air data.

3. DEADLINES:

   All reports available by 1/2 hour before transmission time are plotted on the 1:30 million base chart on which the computer analysis is drawn by the Curve Follower. This chart is enlarged photographically to a 1:20 million scale for transmission. A checklist of key ocean observations used in the computer analysis appears on each chart.

Computer Procedures

The computer analysis proceeds as a separate operation from the hand-plotting already discussed. The analyses are based on ADP (automatic data processing) which begins at the following times:

1. 700 mb; 3 hours after observation time.

2. 500 mb; Preliminary, 1 1/2 hours after observation time, and Operational, 3 hours and 25 minutes after observation time.

3. 300 mb and 200 mb; 3 hours and 25 minutes after observation time.

At these times, all data available in the storage facility of the NMC Communications Computer (IBM 360 System) are fed into the main NMC computer (IBM 7094). Then the ADP program decodes, hydrostatically checks, recomputes and lists all available radiosonde, rawinsonde, pibal reconnaissance and AIREP reports.

Civilian AIREP reports, edited and coded at five Weather Bureau field offices are occasionally available for the analyses started at 3+25 hours after observation (see appendix 10). Approximately 75 military AIREP's primarily over the ocean areas are also available to NMC for the analyses based on this data cut-off time from the USAF Computerized Flight Planning Section at Suitland. For a brief description see:

REFERENCES:

1. Burnett, F. W., "The Role of the Computer in Meteorology", Weatherwise, Vol. 18 No. 5, October 1965.

Computer Analysis Procedures

Details of NMC's complex and ever-changing computer analysis procedures will not be given here. The most recent references available on this subject are:

REFERENCES:

1. Gustafson, A. F., and McDonell, J. E., "The Derivation of First Guess Fields for Objective Analyses, 1000 mb to 500 mb", NMC Technical Memo #31, or

2. Kulawiec, M. H., "The New Machine Analysis", Notes to Forecasters, May 1965.

Philosophy of Analysis

The most important points to understand when using computer analyses are:

1. Computer analyses are made from data derived at a network of grid points spaced about 180 nautical miles apart (see appendix 11). The positions of contours, isotherms, and isotachs drawn by the Curve Follower at NMC, are interpolated from values at points on this fixed grid. Systems with a wavelength (e.g., trough to trough) less than 200 nautical miles in extent will not be evident on these analyses. Furthermore, smoothing during the computer analysis eliminates most "wiggles" or systems smaller than 400 nautical miles in extent.

2. The computer analysis involves two main procedures:

   a. Obtaining the best guess of values of parameters (height, temperature, etc.) from a short-range prognosis or by extrapolation with statistical regression equations from values of parameters already analyzed at other levels. Two references listed above, detail the method of obtaining the 500 guess field. The 300 mb and 200 mb guess fields are obtained as shown in appendix 12.

   b. Adjusting these guess values by a weighted average of the new data available in an influence area surrounding each grid point. The size of the influence area is controlled by the amount of data available. Over the United States this influence area averages about 400 nautical miles in radius. Over ocean areas, where observations are few and far between, a much larger (up to 1000 miles) influence area is searched before enough data for a new analysis are

obtained. Often, over the Pacific Ocean, the guess field becomes the new analysis when no new data are available at any level.

Computation of Parameters

1. Contours and isotherms

On all charts these are computed using the same ADP (automatic data processing) and analysis procedures described in the preceding paragraphs.

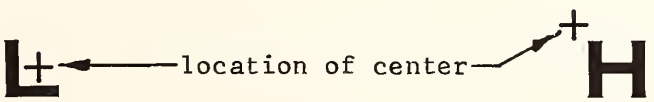
2. Isotachs

Isotachs on the 300 and 200 mb analysis are based on a wind analysis which treats the geostrophic wind as a first-guess and adjusts this by the wind observations. Therefore, over areas with adequate coverage, the new wind data determine the isotachs by the same method and within the scale limitations already discussed for contour and isotherm analyses. Over sparse-data areas, the isotachs are based primarily on the geostropic wind derived from spacing of contours.

Depiction

Contours are depicted by solid linesat 1) 60 meter intervals on 700 mb and 500 mb charts and 2) 120 meter intervals on 300 mb and 200 mb charts. Contours are hand labeled by 3-digit numbers in decameters.

Circulation centers are indicated by "L" for lows and "H" for highs. The "H" symbol for a high center and the "L" symbol for a low center, drawn by the Curve Follower, always bear the relation shown here to the location of the actual center.



Short dashed lines depict 1) isotherms at intervals of 5°C so labeled on 700 mb and 500 mb charts and 2) isotachs at intervals of 20 kt up to 160 knots and intervals of 40 kt above labeled in knots on 300 mb and 200 mb charts.

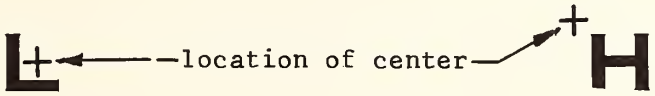
UA-3A; 850 MB ANALYSIS

Computer analyzed for Pacific Section of the Northern Hemisphere (see appendix 15) on a 1:30 million scale for 0000Z and 1200Z. The analysis includes contours and isotherms without plotted data.

Computer Procedures

The ADP (automatic data processing) and analysis procedures begin 1 1/2 hours after observation time and are similar to those discussed in Chart UA-3 for the 500 mb analysis. Height and temperature analyses are made from data derived at a network of grid points spaced about 180 nautical miles apart. The positions of contours, isotherms and low and high centers are interpolated from the grid point data and drawn by the Curve Follower.

Solid lines at 60 meter intervals (30 meter June 15-October 1) are used for contours, hand labeled in decameters. Isotherms are dashed lines at 5° C intervals so labeled. The "H" and "L" symbols, drawn by the Curve Follower, always bear the relation shown here to the actual location of the pressure center.



UA-4; UPPER AIR ANALYSIS

500 mb computer analysis without data for the Northern Hemisphere on a 1:40 million scale for 0000Z only. Includes contours with jet cores drawn by hand.

Description

The analysis is a photo-reduction from the computer analysis on a 1:30 million scale of data available up to 3 + 25 hours after observation time of 0000Z. The automatic data processing (ADP) and analysis procedures used in preparation of this analysis are the same as those described under chart UA-2. Isotachs analyzed by the computer are used as guidance in locating the jet cores.

Depiction

Contours are drawn as solid lines at 60 meter intervals hand-labeled in decameters. High and low centers are printed out with the convention illustrated under chart UA-2. The jet core is portrayed by heavy arrows.

UA-5; THICKNESS ANALYSIS

1000-500 mb computer analyzed for 0000Z and 1200Z, as follows:

a. United States Section at 1:20 million scale, with computer surface analysis, both based on data available at 1 1/2 hours after observation time, transmitted without data.

b. Atlantic and Pacific Sections at 1:20 million scale (see appendix 15) with data computed and plotted by hand.

Plotting Procedures

Atlantic and Pacific Sections:

1. NETWORKS:

All island, OSV, moving ship, and coastal radiosonde and rawinsonde reports are plotted.

2. MODEL:

The plotting models used for radiosonde, rawinsonde and reconnaissance reports and the criteria and model used for AIREP reports are shown in appendix 9. The radiosonde plotting model follows the abbreviated WMO model for upper air data.

3. DEADLINES:

All reports available by 1/2 hour before transmission time are plotted on a 1:30 million scale.

4. PREPARATION:

The following procedures are used for hand computation and plotting of the 1000-500 mb thickness data and thermal winds.

a. Thickness values are determined by subtraction of reported or computed 1000 mb heights from reported 500 mb heights.

b. Thermal winds are computed by vector subtraction of geostrophically measured sea level winds from reported 500 mb (or 18,000 ft) winds. (Geostrophic sea level winds are determined: by measuring spacing and direction of isobars on Chart SA-1 for land stations; and by veering surface wind direction 15° and multiplying velocity by 1.4 for ship reports.)

Computer Procedures: ADP

The automatic data processing which begins 1 1/2 hours after observation time first objectively determines values of sea level pressure and temperature at each grid point of the NMC grid (appendix 11). The procedure uses values of pressure determined from the 12-hour surface forecast and values of temperature derived from the 12-hour thickness forecast, both verifying at the time of the analysis, as the first guess fields. These values are corrected for available surface observational data to give objective sea level pressure and temperature data for the analysis at each grid point. The program hydrostatically derives 1000 mb heights from these data. This 1000 mb field is further modified by available observed 1000 mb heights and by "bogus" data manufactured from subjective surface analyses in areas where no real data are available. 500 mb heights at the grid points are determined as described for Charts UA-2,3. Thickness values at each grid point are computed by simple substraction of 1000 mb heights from 500 mb heights.

Computer Analysis Procedures

The ADP program determines sets of x- and y-coordinates for isobars and thickness isopleths by quadratic interpolation from the grid point values of sea level pressure and thickness respectively. The Curve Follower traces out the lines from the coordinates on a 1:30 million scale. The charts are photo-enlarged to a 1:20 million scale for transmission.

Depiction

United States Section

Surface isobars are depicted by solid lines at 8 mb intervals (4 mb intervals June 15-October 1) labeled by hand by 2-digit numbers, units and tens of pressure in millibars. High and low centers are indicated by convention for numerical analyses described for chart UA-2. Thickness isopleths are drawn as dashed lines labeled in decameters.

Atlantic and Pacific Sections

Thickness isopleths are depicted by solid lines labeled in decameters.

UA-6; TROPOPAUSE AND WIND-SHEAR ANALYSIS

Analyzed by computer in a 2-panel presentation for the 48 states of the United States, southern Canada, northern Mexico and the contiguous ocean areas on 1:20 million scale for 0000Z and 1200Z.

Analysis Procedures

The initialization procedure for the 6-layer numerical prediction model begins 3+25 hours after observation time. After the analysis of height and temperature at the 10 constant pressure surfaces has been completed, the pressure and temperature of the tropopause are determined semi-objectively by a technique developed by Gustafson.

REFERENCES:

1. Gustafson, A. F., "Objective Isentropic Analysis," NMC Technical Memorandum No. 30, Washington, D. C.,1964.

2. Gustafson, A. F., "Objective Analysis of the Tropopause," NMC Technical Memorandum No. 33, Washington, D. C.,1965.

The initialization process computes the pressure and height of the tropopause and other σ-surfaces; and mean u- and v- components of the wind in the layers between the σ-surfaces of the 6-layer numerical prediction model (see appendix 39) at each grid point spaced about 180 nautical miles apart (see appendix 11). The mean layer winds are assumed to to apply at the midpoints of the layers. The heights of the midpoints are determined by averaging the heights of the bounding σ-surfaces.

The maximum wind at the tropopause is computed from the formula:

$$V_{max} = 1/2\left(\overline{V}_2 + \overline{V}_3\right) + 1/4\left(\overline{V}_2 - \overline{V}_1\right) + 1/4\left(\overline{V}_3 - \overline{V}_4\right)$$

where $\overline{V}$ is the mean scalar wind $\left(\sqrt{u^2 + v^2}\right)$ in the layer indicated by the subscript (appendix 39).

The average scalar wind-shear is computed using the formula:

$$\text{Wind-shear} = 1/2 \left(\frac{V_{max} - \overline{V}_1}{Z_{max} - \overline{Z}_1} + \frac{V_{max} - \overline{V}_4}{Z_{max} - \overline{Z}_4} \right)$$

where Z_{max} is the height of the maximum wind or tropopause and $\overline{Z}$ is the mean height in the layer indicated by the subscript (appendix 39).

The numerical analysis procedure duplicates as closely as possible the manual analysis procedure which was once used. The technique presumes

a smoothed wind speed profile with the following characteristics:

1. One maximum wind level.

2. Shears of equal magnitude above and below the level of maximum wind.

3. The maximum wind is at the analyzed tropopause height. (The maximum wind will be at or close to the reported tropopause height at middle and high latitudes. Frequently it will be associated only with a weak stabilization or inversion layer which does not meet the WMO tropopause definition at lower latitudes. The objective analysis procedure places the tropopause at the level of the maximum wind in these areas.)

4. The direction of the wind is constant with height.

5. The smoothed wind field is fitted as closely as possible to the analyzed wind speeds by the computation equations.

The computer program forms stream functions at each grid point from the u- and v-components of the maximum wind at the tropopause level.

By these procedures, the program has computed the following parameters at each grid point:

1. The pressure and height of the tropopause-maximum wind level.

2. The maximum wind speed at the tropopause.

3. The magnitude of the average absolute wind shear from about 10,000 feet above to about 13,000 feet below the tropopause-maximum wind level.

4. The stream function at the tropopause-maximum wind level.

Depiction

x, y-coordinates for points along isopleths for standard values of the various parameters are determined by the computer analysis program. The Curve Follower traces out these points to form lines representing the analyses of the parameters. These analyses are depicted in two panels on a standard 12" X 18" facsimile chart.

The upper panel contains:

1. Isopleths of stream functions depicted by solid lines with arrow barbs indicating direction of flow added by hand. These are parallel to the direction of the maximum wind at the tropopause level with spacing governed by the speed of the maximum wind (equivalent to 120 meter spacing of contours).

2. Isotachs of maximum wind speed depicted as short-dashed lines at 20 knot intervals labeled by hand.

3. The axis of the jet core depicted as long-dashed heavy line with arrowheads, hand-drawn through the centers of the isotach maxima.

The lower panel contains:

1. Isopleths of the height of the tropopause-maximum wind level depicted as solid lines hand-labeled in feet. The contours actually are the intersections of the tropopause with the standard constant pressure surfaces: 150, 200, 250, 300, 400, and 500 mb. The pressures are equated to the reference heights of a standard atmosphere at each constant pressure surface. The labeled heights therefore will be too high where the D-values for the intersections are negative and too low where the D-values are positive.

2. Isopleths of average vertical wind-shear depicted as short-dashed lines hand-labeled in knots per 1000 feet, for each 2 knots of shear.

UA-7; UPPER-AIR ANALYSES - MIA

Hand plotted and analyzed for 0000Z and 1200Z on a 1:20 million scale Mercator projection. The 200 mb chart covers the area from 150 W to 20 E longitude and from 40 S to 45 N latitude. The 850 mb, 700 mb, 500 mb, and 300 mb charts are for the area 120 W to 20 W longitude and 10 S to 45 N latitude. (See appendix 52.) The 850 mb, 700 mb, and 300 mb are transmitted with data only.

Plotting Procedures

1. NETWORKS:

   All available radiosonde, rawindsonde, pibal, and weather reconnaissance reports and AIREPS are plotted. The models of appendix 9 are used except that all AIREPS are entered on the map nearest in time and in height to the report. Reports are entered as received. Reports that appear questionable are checked for accuracy of entry, internal consistency, location, etc.

2. MODELS:

   Station models used are shown in appendix 9.

3. DEADLINES:

   There is no hard cut-off time for data entry and analysis except that imposed by the facsimile transmission schedule. Deadline for entry of data which is normally considered in the analysis is 30 minutes before transmission time.

Analysis Procedures

1. TIME AVAILABLE:

   One analyst works on each chart and completes it in approximately one hour by direct analysis of the data. The 500 mb chart is completed about 6 1/2 hours and the 200 mb chart is completed about 7 hours after observation time.

2. TOOLS AVAILABLE:

   a. NMC mid-latitude and experimental tropical model analysis for comparison and interpretation.

   b. Continuity.

   c. Current surface analysis.

   d. Satellite observations. These have become an essential aid to analysis of the upper level contour charts. Where low

level cloud patterns can be identified, inferences can be drawn concerning low troposphere wind direction, areas of very light winds, and position of ridge lines. Where high level cloud patterns can be identified, inferences can be drawn concerning wind direction, jet stream cores, high level ridges and cold low positions. (The Operations Office (NESC) makes "high troposphere" wind estimates that are transmitted on the South Atlantic coastal facsimile circuit as charts 2401 and 2444.)

e. Mean monthly charts for the tropics.

REFERENCES:

On Jet Streams:

Whitney, L. F., Timchalk, A., and Gray, T. I., Jr., "On Locating Jet Streams From Tiros Photographs", Monthly Weather Review, Vol. 94, No. 3, March 1966, pp 127-138.

On Blow-Offs:

Erickson, Carl O., "Satellite Photographs of Convective Clouds and Their Relation to the Vertical Wind Shear", Monthly Weather Review, Vol. 92, No. 6, June 1964, pp 283-296.

On Cold Core Cyclones:

Frank, Neil L., "The Weather Distribution With Upper Tropospheric Cold Lows in the Tropics", Southern Region Technical Memorandum No. 28, U. S. Weather Bureau, ESSA, September 1966, 6 pages.

On Monthly Mean Charts:

Heastie, H., and Stephenson, P. M., "Upper Winds of the World (Parts 1 and 2)," Geophysical Memoirs No. 103, British Meteorological Office, London, 1960, 217 pages.

Philosophy of Analysis

The basic purpose of the charts is to present a meaningful analysis of wind flow and temperature patterns over the area. To this end:

1. Streamlines are drawn over the area between 20°N and 20°S and contours are drawn poleward of 20°N and 20°S.

2. When it is felt that standard contours do not adequately depict the wind flow in a particular area, intermediate contours and/or streamlines are added or extended poleward of 20°N and 20°S.

3. Where contour heights and wind reports appear inconsistent, priority consideration is given to the winds unless several reports in the same general area indicate a definite ageostrophic flow.

4. Over sparse data areas there is a heavy reliance on aircraft wind reports.

5. Consistency between levels becomes an important analysis tool in sparse data areas, especially in view of item no. 4 above. This is particularly true of the 200-mb and 300-mb levels.

6. An underlying concept for analysis at low latitudes is to model the atmosphere in terms of a lower portion and a higher portion, each with characteristic disturbances. These layers and disturbances appear to behave independently of one another a large part of the time, although they may interact. In this sense, the TOE chart and the 200-mb chart characterize their respective layers, and the intermediate level charts provide information on the transition between the two.

Depiction

Sixty meter contours are analyzed at 500-mb and 120-meter contours at 200 mb poleward from 20 N. and 20 S. and are blended into a streamline analysis between 20 N. and 20 S. Isotherms are drawn for 5-degree intervals and isotachs for 40-knot intervals beginning at a base of 20 knots. Centers of cyclonic circulation are labeled "L" and those of anticyclonic with an "H".

On the 850-mb, 700-mb, and 300-mb charts, only the plotted data are entered.

AC-1; TWELVE-HOUR SURFACE PRESSURE-CHANGE ANALYSIS

Corrected for diurnal variation, issued daily for 0000Z, plus-each-6-hours for North America and surrounding ocean areas on a 1:30 million scale. Charts for 0000Z and 1200Z produced on the computer from data available at 1+30 hours after observation; charts for 0600Z and 1800Z are made from hand analysis.

Hand Analysis Procedures (0600Z, 1800Z)

1. TIME AVAILABLE:

   45 minutes are used for plotting and 45 minutes are used for analysis of the charts.

2. PREPARATION:

   These analyses are plotted, analyzed and traced by hand. Only standard synoptic reporting stations (i.e., SM's) are used over North America. The procedures followed in making the analysis are:

   a. Plotting and subtraction of two pressures, for analysis time and for 12 hours earlier, reported at SM stations on a 1:20 million base chart.

   b. Addition (with proper sign) of 12 hour diurnal changes derived from Weather Bureau Technical Paper No. 1, "Normal Pressures and Tendencies for the United States", Washington 1943.

   c. Analysis of centers of maximum change and isallobars from pressure changes over North America. Over ocean areas, the isopleths are determined by graphical subtraction of the corresponding North American analyses (Chart SA-1). This analysis is performed by an Analyst Assistant, and checked by the Guidance Forecaster doing the surface prognosis.

   d. Photo-reduction of manuscript analysis to 1:30 million scale.

   e. Tracing and labelling of isopleths and centers on the facsimile base chart.

Computer Analysis Procedures

The analyses for 0000Z and 1200Z are computer produced but traced by hand for transmission. The change is between pressures from the objective surface analysis made 1 1/2 hours after the current observation time (end of period) and 8 hours after the observation time 12 hours earlier (beginning of period). The ADP (automatic data processing) and surface analysis procedures are discussed under Chart UA-5. The procedures followed in making the analysis are:

a. Subtraction in the computer of the analyzed pressures at the beginning from those at the end of period at each NWP grid point (see network in appendix 11) and,

b. Addition, with proper regard for sign of the normal diurnal variation at each grid point. The normals have been obtained from 16 years (1950-65) of surface data available in the Extended Forecast Division of NMC.

c. Interpolation of centers of greatest pressure-change plus isopleths of 4 mb changes (zero, $\pm$ 4, etc.) from grid point data. Isopleths and central values are drawn on NMC's Curve Follower.

d. Tracing and labelling of these isopleths and centers on the facsimile base chart are done by hand.

Depiction

Zero changes are drawn as heavy-solid lines, positive changes as light-solid lines and negative changes as light-dashed lines. Isallobars at 4 mb intervals are labeled in millibars of change with proper sign. Centers of maximum change are indicated by the appropriate sign of the change. When available, smoothed tracks of four past positions are entered on the chart.

AC-2; 500 MB 24-HOUR HEIGHT CHANGE ANALYSIS

Produced on the computer from data available at 1 1/2 hours after observation time on 1:30 million scale for North American area for 0000Z and 1200Z.

Computer Procedures

This change chart is the difference between two 500 mb analyses. The analysis at the beginning of the 24-hour period is based on a data cut-off 8 hours after observation time. The current analysis is based on data available at 1 1/2 hours after observation time. Therefore, each succeeding change chart is based on latest version of the earlier analysis. However, there is seldom a significant difference between 1 1/2 and 8-hour analyses over North America since most data are available by 1 1/2 hours after observation. The 500 mb height differences are computed at a network of grid points spaced about 180 nautical miles apart (see appendix 11). The facsimile charts of the height-change analysis drawn by the automatic Curve Follower are interpolated from change values on this fixed grid. Limitations of the Curve Follower equipment restrict drawing of lines (e.g., circular centers) to those 2 inches or more in length, measured on a 1:30 million chart. Therefore, the central 60-meter change-contour will be omitted when the circumference of the central contour is less than 2 inches. The 500 mb analyses on which the change chart is based are made using the general Computer Analysis Procedure described under Chart UA-2.

Depiction

Isallohypses are depicted as solid lines at 60 meters of change intervals hand labeled with appropriate sign in decameters of change. Centers of maximum change and values in decameters are printed by the Curve Follower. 12-hourly past position tracks of centers are added by hand.

AC-3; COMPOSITE MOISTURE INDEX CHART

4 panels at 1:25 million scale, each for United States, southern Canada and northern Mexico; containing the following information plotted and analyzed by hand:

a. Showalter stability index analysis

b. Lowest freezing level analysis

c. Precipitable water analysis, surface to 500 mb

d. Average relative humidity analysis, surface to 500 mb

Plotting Procedures

1. NETWORKS:

All radiosonde reporting stations in United States, southern Canada, and northern Mexico are used if they are available by 3 1/2 hours after data time for charts a and b, and 3 hours after data time for charts c and d (see above).

2. SOURCES:

a. Stability indices are plotted from the early RADAT, or UXUS transmissions. If data are missing, the index is computed by hand from the radiosonde report when it is received at NMC.

b. Freezing level heights are plotted from the 0100Z and 1300Z airway reports (AW). If data are missing, a computation of the freezing-level heights made on the NMC computer is used (see description of method which follows).

c. Precipitable water and average relative humidity data are plotted from listings made up on the NMC computer at 3 hours after data time (see description of methods which follow).

Analysis Procedures

1. TIME AVAILABLE:

About 30 minutes are available for the analyses of the charts.

2. PROCEDURES:

All 4 analyses are performed on the synoptic scale as defined by the network of available upper-air soundings. Care is taken to

maintain continuity of pattern from one chart to the next and consistency with latest surface analysis.

1. Isopleths of stability index are analyzed for intervals of 4 units. Areas of index values less than + 4 are labelled unstable (U). Areas of high index values (above + 4) are labelled stable (S).

2. Although several freezing levels may occur on a sounding, and are plotted on the chart, only the lowest freezing level is analyzed. The surface intersection (32° F) is drawn as a dashed line, and the free-air contours are drawn as solid lines for 4,000 foot intervals. The free-air contours are shown as discontinuous where they intersect smoothed terrain contours in the western United States.

3. The precipitable water is analyzed for intervals of .50" with .25" (dashed)isopleths used to define the pattern when necessary.

4. The relative humidity is analyzed for intervals of 10% for humidities 50% and higher.

REFERENCES:

1. STAFF, A&FD, NAWAC Manual, Part I. pp. 30-45.

2. Showalter, A. K., "A Stability Index for Thunderstorm Forecasting", Bulletin American Meteorological Society, 1953, Vol. 34, pp 250-252.

Computation of Parameters

1. FREEZING LEVEL DATA

First, the pressure of the freezing level is calculated by logarithmic interpolation from the pressure levels reporting temperatures on either side of zero. Next, the height of the freezing level pressure is calculated from heights at the standard pressure levels (e.g., 850 mb, 700 mb, etc.) by logarithmic interpolation or extrapolation, whichever is necessary.

2. PRECIPITABLE WATER (SURFACE TO 500 MB)

The precipitable water is computed from the temperature and dewpoint values at each point on the sounding. The precipitable water observation shown on the chart is the sum of the individual pressure weighted precipitable water values for each sub-layer defined by temperature-dewpoint observations on the sounding. Thus:

$$W_p = \sum_{sfc}^{500} (.0004\ \bar{r}\ dp) \quad \text{where}$$

$$\bar{r} = \frac{.623\bar{e}}{\bar{p} - \bar{e}} \quad \text{and}$$

W_p is the total precipitable water from surface to 500 mb

dp is the pressure difference between top and bottom of each sub-layer

$\bar{r}$ is the average mixing ratio of the sub-layer (dp)

$\bar{e}$ is the average vapor pressure of the sub-layer (dp) and is calculated by the method given in the Smithsonian Tables pp. 347-374.

$\bar{p}$ is the average pressure of the sub-layer (dp)

The hand method used previously is described in appendix 40.

REFERENCES:

1. STAFF, A&FD, NAWAC Manual, Part I, p. 30.

2. Solot, S. B., "Computation of Depth of Precipitable Water in a Column of Air", Monthly Weather Review, April 1939, pp. 100-103.

3. AVERAGE RELATIVE HUMIDITY (SURFACE TO 500 MB)

The relative humidity values are computed first for each sub-layer, weighted by the pressure depth of the sub-layer, summed and pressure averaged over the layer between surface and 500 mb. Thus:

$$\bar{H} = \frac{\sum_{sfc}^{500} (\bar{h})\, dp}{DP} \quad \text{where}$$

$$\bar{h} = 100\, \frac{\bar{e}}{\bar{E}} \quad \text{(in percent)} \quad \text{and}$$

$\bar{H}$ is the average relative humidity in the layer surface to 500 mb (DP)

$\bar{h}$ is the average relative humidity in each sub-layer (dp) where $\bar{e}$ is the average vapor pressure (computed by the method in the Smithsonian Tables pp. 347-374) and $\bar{E}$ is the average saturation vapor pressure for the sub-layer.

AC-4; MAXIMUM AND MINIMUM TEMPERATURE CHARTS

Hand-plotted for temperatures observed during the 12 hours ending at 0000Z and 1200Z, respectively, at 1:12.5 million for the United States area only.

Plotting Procedures

1. NETWORKS:

Station circles for the network used are "blacked in" on the base chart. A map of the network stations, with identifiers, is given in appendix 26. Sources for data are the SM's on Service C with fill-ins from the aviation observations on Service A.

2. MODELS:

When both a city office and an airport office send temperatures, the city office temperature is plotted on-station and the airport temperature is listed in a printed box, labelled AIRPORT TEMP, on the right hand edge of the chart.

The RECORD TEMPS box printed in the Gulf of Mexico is filled in from the fifth group of the SM (Hi-Lo report) for all records reported on each set of data.

Contraction	Type of Temperature Record
HIXFM	HIghest eXceeded For the Month
LOXFM	LOwest eXceeded For the Month
HIEFM	HIghest Equaled For the Month
LOEFM	LOwest Equaled For the Month

Spring temperatures, March, April, and May

HIXSE	HIghest eXceeded So Early
LOXSL	LOwest eXceeded So Late
HIESE	HIghest Equaled So Early
LOESL	LOwest Equaled So Late

Autumn temperatures, September, October, and November

HIXSL	HIghest eXceeded So Late
LOXSE	LOwest eXceeded So Early
HIESL	HIghest Equaled So Late
LOESE	LOwest Equaled So Early

All time records, (since observations began)

HIXAT	HIghest eXceeded for All Time
LOXAT	LOwest eXceeded for All Time
HIEAT	HIghest Equaled for All Time
LOEAT	LOwest Equaled for All Time

3. DEADLINES:

All data available by 5 minutes before transmission time can be plotted on the chart.

AC-5; OBSERVED 24-HOUR PRECIPITATION AMOUNTS (INCLUDING TRACES)

Plotted by hand on a 1:12.5 million base for the United States, southern Canada, and northern Mexico, once-per-day at 1200Z. The chart is transmitted at 1415Z on the Forecast Center Facsimile Circuit and at 1532Z on the National Facsimile Chart.

Plotting Procedures

1. NETWORKS:

   All available stations are plotted. Sources are 1200Z SM's on Service C, 1200 AW's on Service A, and SR's on Service C and RAWARC. Also, 6 hourly precipitation observations are used to plot traces.

2. MODELS:

   All observations that space allows are plotted in hundredths of an inch on the base chart. Additional reports, which can't be fitted on the base chart are plotted in a special column form, printed on the right side of the chart.

3. DEADLINES:

   Data can be plotted on the chart until about 5 minutes before transmission time. This chart is transmitted twice; first, at 1415Z (on the Forecast Center Facsimile Circuit) when only the basic network of synoptic (SM) and aviation (AW) observations are available, and later at 1532Z on the National Facsimile Circuit when more observations from hydrologic stations (SR's) have been received.

AC-6; OBSERVED SNOW COVER CHART

Plotted by hand, four times per day.

a. At 0000Z and 1200Z, on a 1:20 million base for the United States area.

b. At 0600Z and 1800Z, on a 1:25 million base chart in the lower right panel of the Upper Level Winds Aloft Chart (AC-7).

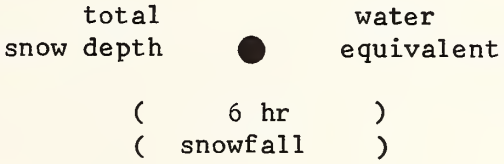
Plotting Procedures

1. NETWORKS:

All available stations are plotted. The 1200Z chart contains the greatest number of observations, since most stations report the depth on the ground at that time. At 0000Z, only those stations reporting precipitation during the past 6 hours, report snow depths. Water equivalents are usually reported only on Tuesdays and Thursdays. NMC seldom receives many 0600Z and 1800Z snow depth reports.

2. MODELS:

The plotting model used on all four charts is:



3. DEADLINES:

All snow accumulation or snow depth reports available by 5 minutes before start of transmission are used.

AC-7; WINDS ALOFT AND TROPOPAUSE CHART

Hand-plotted from observations at 0000Z plus-each-6 hours. The data are presented in the following 3 charts, each containing four 1:25 million panels of the United States, southern Canada and northern Mexico:

a. Low Levels, Winds Aloft, containing 2nd standard level above surface (gradient), 850 mb, 8,000 foot, and 700 mb winds.

b. Intermediate Levels, Winds Aloft, containing 14,000 foot, 20,000 foot, 25,000 foot, and 300 mb winds.

c. Upper-Levels, Winds Aloft, containing 35,000 foot, 200 mb, and 50,000 foot winds. At 0000Z and 1200Z, the fourth panel contains tropopause data. At 0600Z and 1800Z, the fourth panel contains 6-hour snowfall amounts (see AC-6 for a description of this chart).

   Also at 0600Z and 1800Z the mandatory-level heights, temperatures and dewpoints from the United States stations taking intermediate radiosonde observations are plotted on the 5,000 foot (850 mb), 10,000 foot (700 mb), 20,000 foot (500 mb), and 30,000 foot (300 mb) panels.

Plotting Procedures

1. NETWORKS:

   All available data from the upper-air network over the United States and southern Canada are plotted. The observations at OSV's November and Papa, and at Bermuda are inserted off-position in special boxes along the edges of each chart. The basic source for United States upper-wind data are the UJ and UC collectives on Service C. In case of missing reports, the east coast Hurricane Circuit (when in service), and the RAWARC circuit, are checked for late transmissions. Canadian wind data are available at NMC on a special Suitland-Dorval Circuit and on Service O Circuits.

2. MODELS:

   The plotting model used is an abbreviated (wind only) version of the model shown in appendix 9. The height, wind, and temperature at the tropopause are obtained from the coded tropopause information

in the radiosonde report. Heights are converted from meters to feet. The plotting model used is the same as that used for constant pressure charts and is shown in appendix 9. This same model is used for plotting mandatory level information when available at 0600Z and 1800Z.

3. DEADLINES:

The data are plotted until 5 minutes before transmission begins on the first Winds Aloft Chart.

SP-1; NWP SURFACE PROGNOSIS

Computer produced 24- and 36-hour objective sea level pressure prognoses, twice a day from 0000Z and 1200Z initial observations, covering the NMC Front Half section of the Northern Hemisphere (see appendix 14) on a 1:30 million scale. Transmitted with corresponding 1000-500 mb thickness prognoses superimposed.

1. Numerical Models. The sea level pressure forecasts are derived from the objective 1000 mb prognoses produced by the 6-Layer (PE) Numerical Prediction Model, which is the operational model at NMC. The Reed model, based on the 3-Level Baroclinic Model, is run as backup when the PE model fails. PE and 3-level models are described under Chapter 6, Chart UP-2.

1.1 The 6-Layer (PE) Numerical Prediction Model. The 1000 mb prognosis is a part of the comprehensive prediction package produced by the PE operational forecast run which begins three hours and twenty-five minutes after observation time.

1.1.1 Computer Forecast Procedures. At the initial and forecast output times, the PE model provides pressures and heights on the σ-surfaces and mean potential temperatures in the σ-layers (see appendix 39) at each grid point of the NWP grid (see appendix 11). The lowest σ-surface in the PE model is the surface of the earth. 1000 mb heights, initial and forecast, are determined as follows:

a. The mean potential temperatures in the boundary layer and the lowest tropospheric layer are extrapolated to the layer between the surface of the earth and the 1000 mb surface, assuming a linear variation with π, a function of pressure (the Exner function):

$$\pi = \left(\frac{p}{1000}\right)^{\frac{R}{c_p}}$$

b. The difference in height between the surface of the earth and the 1000 mb surface is computed from the pressure difference and mean potential temperature in this layer by means of the hydrostatic equation. Application of the height difference to the given height of the earth's surface (see appendix 17) determines the 1000 mb height at each grid point.

c. The difference between the 1000 mb heights computed for the initial time and at the forecast output time represents the forecast 1000 mb height tendency. This tendency is added to the analyzed 1000 mb grid point height derived entirely from the objective sea level pressure analysis produced as a part of the initialization procedure for the PE model (see Chart UP-2) to give the forecast 1000 mb heights at each grid point.

1.1.2 Philosophy of Prognosis. The tendency technique produces a 1000 mb height field which reflects the pressure reduction procedures used in the observational program rather than those used in the PE model. In mountain areas where the 1000 mb surface is often below ground level, the PE model temperatures extrapolated to the layer between earth's surface and 1000 mb are consistently too warm. Consequently, 1000 mb heights computed using these temperatures are usually lower than those computed from observed radiosonde data. The tendency technique effectively eliminates this result of the pressure reduction procedure and produces forecast 1000 mb height fields which resemble those analyzed from observed data.

1.1.3 Computation of Parameters. The PE model numerical prediction run provides forecasts of 500 mb height at each grid point at output times. Subtraction of 1000 mb from 500 mb heights produces the 1000-500 mb thickness forecast at each grid point.

The 1000 mb heights are converted to sea level pressures p_s by this approximate formula:

$$p_s = 1000 \left(\frac{2\,RT + g\,z_o}{2\,RT - g\,z_o}\right)$$

where R = gas constant and T is an estimate of the 1000 mb temperatures given by:

$$T = 14.3\ (°C) + 0.0005266\ \Delta z_{1000}^{500}$$

where Δz_{1000}^{500} is the 1000 mb to 500 mb thickness (in cm).

1.2 The Reed Model. This simple 2-level barotropic vorticity model was developed by Dr. Richard J. Reed of the University of Washington to incorporate the skill of the barotropic or baroclinic 500 mb numerical forecasts into numerical 1000 mb prognosis.

1.2.1 The Prediction Equation. The equation states a simple conservation principle:

$$\left(a\,\bar{z}_o - z_o + b\,z_5\right)^f = \left(a\,\bar{z}_o - z_o + b\,z_5\right)^u$$

where the subscript "f" stands for forecast time and "u" for upstream point; $(a\,\bar{z} - z_o)$ is proportional to the 1000 mb vorticity and $b\,z_5$ is proportional to the 500 mb height. The equation states that the value of the conservation function at any grid point is predicted to be the same as that at the upstream end of a trajectory, determined by an "equivalent advecting wind field", terminating at the grid point in question.

1.2.2 Computer Forecast Procedures. The computer program uses the following data available at each grid point of the NWP grid (see appendix 11):

a. 1000 mb and 500 mb initial heights.

b. Forecast 500 mb heights at each hourly time step out to 48 hours from the 3-level baroclinic model forecast (see UP-2).

The procedure begins with the 12-hour 500 mb forecast. At each grid point:

a. A 12-hour trajectory is constructed upstream (back in time) using approximately 55% of the geostrophic 500 mb flow determined from the 500 mb height field at each hourly time step. These give the location points of the initial 1000 mb heights which will arrive at each grid point after the first 12-hour period of the forecast.

b. One-half of the prognostic 500 mb height change along the trajectory (between the initial and terminal points) is added to the 1000 mb height advected to each grid point.

This procedure results in a set of 12-hour prognostic 1000 mb heights for each grid point.

The forecast computation then transfers to the 24-hour 500 mb prognosis. The same procedure constructs trajectories upstream to points for which 1000 mb heights may be interpolated from the 12-hour forecast grid point values. Half of the 500 mb height change along the twelve to twenty-four hour trajectory is added to give the 24-hour forecast 1000 mb heights at each grid point. The process is repeated for the 36- and 48-hour forecasts.

1.2.3 Philosophy of Forecast. The Reed Model operates on the principle that changes in the layer between 1000 mb and 500 mb result from simple horizontal advection. The conservation equation states that when the 1000 mb vorticity (circulation) increases during the forecast, the 500 mb heights decrease, and vice versa.

The model contains a factor which is introduced to take account of terrain effects on both the wind flow and vertical motion. The term is not adequate in the areas of large mountains as well as those areas influenced by their proximity. The forecasts are poorest in these regions.

1.2.4 Computation of Parameters. The Reed model provides forecasts of 1000 mb height at each grid point for output times; the 3-Level Baroclinic Model, the 500 mb heights for the corresponding times.

a. Subtraction of 1000 mb height from 500 mb height gives the 1000-500 mb thickness forecast at each grid point.

b. 1000 mb heights are converted to sea level pressures at each grid point by the same procedure as that used in the PE model.

2. References.

a. Reed, R. J., "Experiments in 1000 Mb Prognosis", Technical Memorandum No. 26, National Meteorological Center, U. S. Department of Commerce, Weather Bureau, 1963.

b. Reed, R. J., "On the Practical Use of Graphical Prediction Methods", Monthly Weather Review, Vol. 88, No. 6, June 1960, pp 209-218.

c. Roberts, C. F., "Present and Future Operational Prediction Models", ESSA Technical Note 16-Fcst-3, October 1965.

d. Shuman, F. G., and J. B. Hovermale, "An Operational Six-Layer Primitive Equation Model", Journal of Applied Meteorology, Vol. 7, No. 4, August 1968.

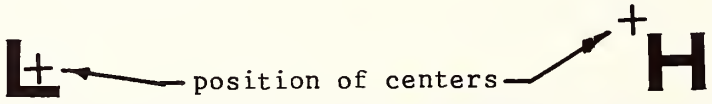
e. Technical Procedures Bulletin No. 7: "Sea-Level Pressure Forecasts from 6-Layer (PE) Numerical Prediction Model", Technical Procedures Branch, ESSA, Weather Bureau, September 1967.

3. Derivation of Output. A data processor on the IBM 7094II computer determines the x- and y-coordinates of closely spaced location points along standard isobars and thickness isopleths by quadratic interpolation from the grid point values of sea level pressure and 1000-500 mb thickness. The Curve Follower traces out the location points to draw the analyses for the forecast output times.

3.1 Depiction. The isopleths are depicted as follows:

a. Isobars are drawn as solid lines at 8 mb intervals with intermediate isobars occasionally drawn as long-dashed lines at 4 mb intervals in areas of weak pressure gradient. (Solid lines at 4 mb intervals are drawn routinely June 15 - October 1.) Isobars are hand labeled by 2-digit numbers, tens and units of pressure in millibars.

Positions of low and high centers are plotted by the Curve Follower in the standard way:



These may be labeled by 3-digit numbers, in millibars with thousands digit omitted.

b. Thickness isopleths are drawn as short dashed lines at 60 meter intervals, hand labeled in decameters. Centers of warm and cold pools may be indicated by + labeled in decameters.

Derivation

The 500-mb prognoses used in this forecast are based on the 3-level baroclinic model run from the same set of initial data as described under chart UP-2.

The Reed model computes a forecast of 1000-mb heights at the network of grid points shown in appendix 11. The thickness forecast at each grid point is found by subtracting the Reed 1000-mb height from the 500-mb 3-level baroclinic height forecast.

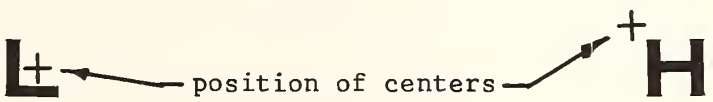
The 1000-mb heights are converted to sea level pressures by the same technique as that used with the 6-layer model.

C. DEPICTION

The computer program determines the positions of sea level isobars and thickness isopleths as sets of x-, y-coordinates by quadratic interpolation from the grid point values. The Curve Follower traces out both sets of lines from these coordinates.

Isobars are drawn as solid lines at 8-mb intervals with intermediate isobars occasionally drawn as long-dashed lines at 4-mb intervals in areas of weak pressure gradient. (Solid lines at 4-mb intervals are drawn routinely June 15 - October 1.) Isobars are hand labeled by 2-digit numbers, tens and units of pressure in millibars.

Positions of low and high centers are plotted by the Curve Follower in the standard way:



These may be labeled occasionally by 3-digit numbers, in millibars with thousands digit omitted.

Thickness isopleths are drawn as short dashed lines at 60-meter intervals, hand labeled in decameters. Centers of warm and cold pools may be indicated by + labeled in decameters.

SP-1A; NWP SURFACE PROGNOSES

24- and 30-hour numerical sea-level pressure prognoses issued twice daily based on 0000Z and 1200Z initial data on a 1:20 million scale. Area covered is North America, the North Atlantic, Europe, and the Arctic on one section and the northern portion of the North Pacific on another (XX-1 cut, appendix 25).

Description

These prognoses are produced by the 6-layer (PE) numerical prediction model in the same manner as those described under chart SP-1. They differ only in area covered, period (30- instead of 36-hour) and scale 1:20 instead of 1:30 million). They are transmitted over the High Altitude Facsimile Circuit as guidance for Significant Weather Prognoses in the Pacific area.

Derivation and depiction are as described under chart SP-1.

SP-2; 30-HOUR SURFACE AND 1000-500 MB THICKNESS PROGNOSIS

Manually produced, covering the NMC Front Half section of the Northern Hemisphere (see appendix 14) on a 1:30 million scale twice a day valid at 0000Z and 1200Z based on 1800Z and 0600Z initial surface analyses respectively.

1. Numerical Guidance. The entire output of the 6-Layer (PE) Numerical Prediction Model (or of the 3-Level Baroclinic Model used as backup) is available for use in the preparation of the 30-hour surface prognosis. The primary tools from this package are:

a. The objective 36-hour sea level pressure and 1000-500 mb thickness prognoses (see Chart SP-1).

b. The 36-hour 500 mb prognosis (see Chapter 6, Chart UP-4).

Other products available for evaluation and use include the following:

a. The objective 12-, 24-, and 48-hour sea level pressure and 1000-500 mb thickness prognoses (see Chart SP-1).

b. The 24- and 36-hour 500 mb absolute vorticity prognoses (see Chapter 6, Chart UP-8).

c. The 6-, 12-, 24-, and 36-hour vertical velocity prognoses (see Chapter 6, Chart UP-2).

d. Forecast 24-hour height changes as indicated by the 24- and 48-hour 500 mb numerical prognoses (see Chapter 6, Chart UP-4).

e. Barotropic 12-, 24-, and 36-hour 500 mb prognostic heights and absolute vorticity with initial analyses (see Chapter 6, Chart UP-1).

2. Forecast Tools. These include the following which are used in varying degrees in all short range surface prognoses at NMC:

a. Interrelationships between the initial surface, 500 mb, 1000-500 mb thickness and 500 mb absolute vorticity analyses.

b. 3-hour tendencies and 12-hour changes of sea-level pressure; 24-hour changes of 500 mb height.

c. Continuity (past history).

d. Empirical and physical atmospheric relationships derived from various studies (see references).

3. Forecast Procedures. Procedures are centered on evaluation of the available numerical guidance by the Chief of the Forecast Section and his team of forecasters. The trends indicated by the latest sets of PE (or 3-level

baroclinic) and barotropic prognoses, knowledge of systematic errors (see appendix 18 for barotropic), and study of the most recent errors are used in modifying the 36-hour 500 mb prognosis. The modified 500 mb prognosis is used in modifying the objective PE (or Reed) 36-hour sea level pressure prognosis.

3.1 Surface Prognosis. A 36-hour forecast valid at the same time as the 30-hour surface prognosis has already been prepared and transmitted as part of Surface Prognostic Package A or B (see Chart SP-3). The 30-hour surface prognosis is an updated version, extended over the Atlantic and Pacific Oceans and with isobaric pattern added. It stems from the same numerical guidance as the 36-hour prognosis but is based on a surface analysis which is six hours later.

The main contributions of the prognostic analyst in modifying the objective PE sea level pressure forecast are to:

a. assess the effect of the modifications to the numerical 36-hour 500 mb prognosis,

b. add details in frontal structure,

c. improve the appearance of pressure patterns by correcting gradients and adding typical climatological features, and

d. provide orographic detail.

3.2 1000-500 Mb Thickness Prognosis. The subjective sea level pressure forecast (converted to a 1000 mb forecast field) is subtracted graphically from the modified 36-hour 500 mb prognosis to arrive at a preliminary thickness forecast which uncovers areas where:

a. The apparent thickness change is unreasonable (i.e., too much or too little for indicated advection and vertical motion pattern), and

b. Typical relationship between the surface and thickness patterns is violated (see appendix 4 for thickness models).

The surface and/or 500 mb forecasts then are adjusted to arrive at a more reasonable and final forecast thickness pattern.

An alternative procedure in which the 36-hour 500 mb prognosis is not modified explicitly may be followed. The modification effort is concentrated on the objective 36-hour PE sea level pressure prognosis. Adjustments are made for all of the factors listed under section 3.1. The resulting forecast pressure field is converted to a 1000 mb contour field which is subtracted graphically from the unmodified 36-hour forecast 500 mb contour field. The 1000-500 mb forecast thickness then is adjusted to correct for unreasonable forecast thickness changes and to exhibit typical relationships between thickness and surface frontal patterns (see appendix 4). This thickness field in this procedure contains the implied modifications in the 500 mb prognosis.

In both procedures, the modified 500 mb prognoses may be recovered by converting the forecast isobars to 1000 mb contours (8 mb $\approx$ 60 meters) and graphically adding them to the forecast 1000-500 mb thickness contours.

4. References.

a. George, J. J., et al., "Forecasting Relationships Between Upper Level Flow and Surface Meteorological Processes," Geophysical Research Papers, No. 23, Air Force Cambridge Research Center, Cambridge, Massachusetts, August 1953.

b. Ostby, F. P., and Veigas, K. W., "A Moving Co-Ordinate Prediction Model Applied to East Coast Cyclones," Scientific Report No. 1, Contract No. AF 19 (604)-5207, The Travelers Weather Research Center, November 1960.

c. Riehl, H., Haggard, W. H., and Sanborn, R. W., "On the Prediction of 24-Hr Hurricane Motion," Journal of Meteorology, Volume 13, 1956, pp. 415-420.

5. Depiction.

5.1 Fronts. These are depicted using WBAN Weather Analysis symbols (see appendix 2) further defined by 3-digit code figures with a bracket to the right. The code for type, intensity, and characteristic ($F_tF_iF_c$) is in accordance with the "Front Group (3)" format of the Abridged United States Weather Analysis Code (January 1, 1949, amended) shown in appendix 3.

5.2 Isobars. These are depicted by solid lines at 8 mb intervals. Occasionally, intermediate isobars at 4 mb intervals, depicted by long-dashed lines are used to define the pattern in areas of weak pressure gradient. Isobars are labeled by 2-digit numbers, tens and units of pressure in millibars. The 8 mb interval easily converts to 60 meter 1000 mb contours for graphical addition to thickness contours to produce the modified 500 mb prognosis.

5.3 Pressure Centers. These are indicated by "L" for low and "H" for high, labeled for central pressure by underlined 2-digit numbers; tens and units of pressure in millibars. The instantaneous direction (to 36 compass points), is indicated by an arrow labeled in whole knots for speed (STNRY indicates system is stationary), valid for the time of the prognosis only.

5.4 Thickness. The 1000-500 mb thickness contours are depicted by dotted lines at 60 meter intervals labeled in decameters.

SP-3; 24-, 36-, AND 48-HOUR SURFACE PROGNOSES

Manually produced, including forecasts of fronts, pressure centers and isobars (except no isobars on 36-hour prognosis); covering portions of the United States, southern Canada and northern Mexico (see NMC U. S. section, appendix 14) on a 1:20 million scale; plus on-time precipitation and cloud (overcast or overcast with breaks) forecasts for United States portion and Canada south of 49° N latitude. Prepared twice a day from 0000Z and 1200Z initial data.

1. Description. These prognoses are a part of Surface Prog Packages A and B. Other charts included in these packages are the 4-panel Probability of .01 Precipitation (Chart SP-5) and Maximum/Minimum Temperature and 24-Hour Change (Chart SP-8) forecasts.

2. Numerical Guidance. The entire output of the 6-Layer (PE) Numerical Prediction Model (or of the 3-Level Baroclinic Model used as backup) is available for use in the preparation of this set of surface prognoses. This primary numerical guidance includes:

a. The objective 24-, 36-, and 48-hour sea level pressure and 1000-500 mb thickness prognoses (see Chart SP-1).

b. The 12-, 24-, 36-, and 48-hour 500 mb height prognoses (see Chapter 6, Charts UP-2 and UP-4).

c. The 24- and 36-hour forecasts of 500 mb absolute vorticity (see Chapter 6, Chart UP-8).

d. The 6-, 12-, 24-, 36-, and 48-hour vertical velocity prognoses (see Chapter 6, Chart UP-2).

e. The 12-, 18-, 24-, 36-, and 48-hour forecasts of mean relative humidity in the layer surface to 500-400 mb and quantitative precipitation forecasts for each 12-hour period out to 48 hours from initial time (see Chapter 6, Chart UP-3). When the PE model does not run, a SLYH forecast (see references) is prepared based on the 3-Level Baroclinic Model used as backup.

f. Initial and 12-, 24-, and 36-hour forecasts of lifted index as an indicator of instability (see Chapter 6, Chart UP-7).

g. Forecast 24-hour height changes as indicated by the 24- and 48-hour 500 mb numerical prognoses.

h. Barotropic 12-, 24-, and 36-hour 500 mb prognostic heights and absolute vorticity with initial analyses (see Chapter 6, Chart UP-1).

3. Forecast Tools. These include the following which are used in varying degrees in all short range surface prognoses at NMC:

a. Interrelationships between the initial surface, 500 mb, 1000-500 mb thickness and 500 mb absolute vorticity analyses.

b. 3-hour tendencies and 12-hour changes of sea level pressure; 24-hour changes of 500 mb height.

c. Continuity (past history).

d. Empirical and physical atmospheric relationships.

4. Forecast Procedures. Procedures are centered on evaluation of the available numerical guidance by the Chief of the Forecast Section and his team of forecasters. The trends indicated by the latest sets of PE (or 3-level baroclinic) and barotropic prognoses, knowledge of systematic errors (see appendix 18 for barotropic), and study of the most recent errors are used to modify the 24-, 36-, and 48-hour 500 mb prognoses. The changes at 500 mb are used in modifying the objective PE (or Reed) corresponding sea level pressure prognoses.

4.1 Surface Prognoses. The objective sea level pressure prognoses (PE or Reed) are also subject to characteristic errors. The main contributions of the prognostic analyst in modifying these objective forecasts are to:

a. assess the effect of modifications to the numerical 500 mb prognoses,

b. apply corrections based on systematic and most recent error patterns,

c. add details in frontal structure,

d. improve the appearance of pressure patterns by adjusting gradients and adding typical climatological features, and

e. provide orographic detail.

4.2 Precipitation and Cloud Forecasts. Procedures used in precipitation and cloudiness forecasting are based on the "Model-of-the-Day" concept. The forecaster sets up an initial relationship between the observed clouds and precipitation and the concurrent analyzed surface fronts, sea level pressure and 500 mb contour patterns and from the vertical velocity field (estimated from the 6-hour PE forecast) and barotropic and baroclinic vorticity and vorticity advection patterns. Moisture distribution as revealed by precipitable water totals, mean relative humidity surface to 500 mb, temperature--dew point spreads aloft and dew points at the surface together with indications of instability from RADAR observations, lifted index and Showalter stability index are considered also.

The Model-of-the-Day then is used as the basis for reassociation of clouds and precipitation with the prognostic surface and upper air features for valid times of the prognoses. This first estimate of the forecast cloud and precipitation pattern may be adjusted as a result of any of the following

indications from the numberical guidance forecasts:

a. Change in intensity of upper air systems reflected by change in vertical velocity patterns and vorticity advections.

b. Changes in mean relative humidity and the corresponding quantitative precipitation forecasts from the PE model.

c. Changes in lifted index as an indicator of the possibility of convective precipitation.

Modifications in the numerical 500 mb and sea level pressure prognoses to correct systematic errors affect the cloud and precipitation forecasts (see appendix 19, for example). Finally, details resulting from orography and the effects of water bodies are included if they are on a sufficiently large scale.

5. Depiction.

5.1 Fronts. Prognostic surface fronts are depicted according to the symbols shown in appendix 2, and coded using the last 3 characters ($F_tF_iF_c$) of the Frontal Group in the Abridged United States Weather Analysis Code (appendix 3).

5.2 Isobars. These are drawn as solid lines at 8 mb intervals, with dashed lines at 4 mb intervals added to define the pattern in areas of weak pressure gradient.

5.3 Pressure Centers. High and low pressure centers are indicated by the usual "H" and "L" respectively, labeled in millibars (two digits with hundreds and thousands digits omitted). The instantaneous direction of motion is indicated by an arrow (to 36 compass points) labeled with speed in knots (STNRY indicates stationary), valid for the time of the prognosis only.

5.4 Precipitation. Forecast areas are depicted in accordance with the format described in appendix 27.

5.5 Clouds. Forecast areas of overcast and/or overcast-with-breaks are outlined by scalloped lines. These areas may include all types of cloudiness except that cirrus not associated with large scale surface systems, such as jet-stream cirrus and cirrus associated with thunderstorms.

SP-4; LOW LEVEL SIGNIFICANT WEATHER PROGNOSIS

Manually produced 12- and 24-hour prognoses of aviation parameters for portions of the United States, southern Canada and northern Mexico [see NMC U. S. (Panel) section, appendix 14] on a 1:25 million scale. Prepared four times a day from 0000Z, 0600Z, 1200Z and 1800Z initial data.

1. Description. This chart and the High Level Significant Weather Prognosis (Chapter 6, Chart UP-11) comprise the NMC FN Depiction Prognosis, a planning forecast for aviation. Twice a day, from 0000Z and 1200Z initial data times, the prognoses serve also as guidance for public weather forecasts. 12- and 24-hour prognoses are presented in two panels for each time period.

The upper panels contain forecasts of the following parameters for the valid times:

a. Fronts.

b. Isobars (only on 24-hour prognoses of sets prepared from 0000Z and 1200Z initial data times).

c. Pressure centers.

d. Precipitation areas. Thunderstorms imply moderate or greater turbulence.

e. Areas of extensive stratus and/or fog.

The lower panel forecasts for the valid times include the following:

a. Areas of 6/10 or greater cloud coverage in two categories:

1) bases at or below 5,000 feet above ground, and

2) bases between 5,000 and 25,000 feet above ground.

b. Topography of the lowest freezing level. Icing is implied in all clouds above the freezing level.

c. Moderate or greater turbulence not associated with thunderstorms.

Forecasts of weather parameters are not made for northern Mexico.

2. Numerical Guidance. The entire output of the 6-Layer (PE) Numerical Prediction Model (or the 3-Level Baroclinic Model when used as backup) is available for use. This is the same material that was used in preparing the 24-, 36- and 48-hour prognoses described under Chart SP-3 and the 30-hour under Chart SP-2. No new numerical guidance is available for the 12- and 24-hour forecasts.

The barotropic numerical forecast (see Chapter 6, Chart UP-1), is transmitted at about the same time as the prognoses from 0000Z and 1200Z initial data but is not available early enough for use in their preparation.

3. Forecast Tools. These include the following which are used in vary-degrees in all short range forecasting at NMC:

a. Interrelationships between the initial surface, 500 mb, 1000-500 mb thickness and 500 mb absolute vorticity analyses.

b. 3-hour tendencies and 12-hour changes of sea level pressure; 24-hour changes of 500 mb height.

c. Continuity.

d. Low level cloud and weather analysis prepared for the data on the Weather Depiction Analysis (see Chapter 2, Chart SA-4).

e. 850, 700 and 500 mb analyses (see Chapter 3, UA-1).

f. Moisture, stability index and freezing level analyses (see Chapter 4, Chart AC-3).

g. Empirical and physical atmospheric relationships.

4. Forecast Procedures. Procedures are centered on the evaluation of the available numerical guidance by the Chief of the Forecast Section and his team of forecasters as described under Charts SP-2 and SP-3.

4.1 Surface Prognosis. Forecasts of the positions of fronts and pressure centers are interpolated directly from the previously transmitted 24- and 36-hour prognoses of Surface Prog Packages A and B (see Chart SP-3) for the forecasts prepared from 0600Z and 1800Z initial times respectively.

The 12- and 24-hour prognoses prepared from 0000Z and 1200Z initial times represent updated versions of the respective 24-hour forecast from the A and B packages and of the 30-hour Surface Prognosis (Chart SP-2) verifying at the same times. The 12-hour numerical forecasts are reevaluated in the light of the new 0000Z or 1200Z surface and 500 mb analyses to determine modifications to the earlier prognoses.

4.2 Precipitation and Clouds. The procedures are based on the "Model-of-the-Day" concept. The forecaster sets up an initial relationship between observed clouds (including fog and stratus) and precipitation and the concurrent analyzed surface fronts, sea level pressure and 500 mb contour patterns, vertical motion (the 6-hour PE forecast), and baroclinic vorticity and vorticity advection patterns. Moisture distribution as revealed by precipitable water totals, mean relative humidity surface to 500 mb, temperature-dew point spreads aloft and dew points at the surface together with indications of instability from RADAR observations, lifted index and Showalter stability index are considered also.

The Model-of-the-Day then is used as the basis for reassociation of clouds and precipitation with the prognostic surface and upper air features for valid times of the prognoses. This first estimate of the forecast cloud and precipitation patterns may be adjusted as a result of any of the following indications from the numerical guidance forecasts:

a. Change in intensity of upper air systems reflected by changes in vertical velocity and vorticity advection patterns.

b. Changes in mean relative humidity and the corresponding precipitation forecasts from the PE model.

c. Change in lifted index as an indicator of the possibility of convective precipitation.

Modifications to the numerical 500 mb and sea level pressure prognoses to correct for systematic errors affect the cloud and precipitation forecasts (see appendix 19, for example). In the forecasts made from 0000Z and 1200Z initial data, the evaluation of the 12-hour numerical guidance could lead to further modification affecting the cloud and precipitation forecast. Finally, details resulting from orography and the effects of bodies of water are included if they are on a sufficiently large scale. Forecasts of extended areas of fog and stratus not associated with storm systems are based on forecasts of surface pressure patterns favoring their formation or continued existence. Forecasts of isolated fog or stratus occurrences covering small areas are not attempted.

4.3 Freezing Level. The freezing level analysis (see Chapter 4, Chart AC-3) is the starting point for this forecast. The primary tool is the 1000-500 mb thickness forecast which is related to freezing level by means of a nomogram developed at the National Meteorological Center (see references).

a. Forecasts from 0000Z and 1200Z initial data: the 36-hour thickness forecast transmitted earlier with the 30-hour surface prognosis (see Chart SP-2) is modified for the updated features in the new 24-hour surface prognosis verifying at the same time. The freezing levels derived from this modified thickness pattern apply directly in the 24-hour forecast of the set. The isopleths of freezing level are adjusted for the 12-hour prognosis from their association with the surface frontal patterns.

b. Forecasts from 0600Z and 1800Z initial data: these surface prognoses are derivatives of the 24-hour prognosis from Surface Prog Package A or B (see Chart SP-3). They verify six hours before and after the 24-hour prognosis for which an associated thickness pattern has been determined. The freezing level forecast is derived from this thickness pattern and adjusted for the frontal positions on the 12-hour prognosis verifying six hours before and the 24-hour prognosis verifying six hours after.

The temperature forecasts transmitted as a part of Surface Prog Package A or B (see Chart SP-8) are used as guidance in all four freezing level forecasts

to fix the location of the surface freezing line and 4,000 foot contour.

4.4 Turbulence. This forecast designates points where moderate or greater turbulence may be expected. These points may be associated with:

a. Strong low level baroclinic zones such as cold fronts and heavy precipitation areas.

b. CAT areas associated with the jet core, particularly in those layers on the left side (looking downstream) where values of vertical wind shear are expected to be above 5 or 6 knots per 1000 feet and cold-air advection is taking place.

c. CAT areas associated with sharp V-shaped upper-level troughs or in the neck of cut-off lows.

d. Turbulence associated with jet streams oriented at right angles to mountain ranges with velocities at least 25 knots at the top of the range.

5. References.

a. Colson, DeVer, "Analysis of Clear Air Turbulence Data for March, 1962", Monthly Weather Review, Volume 91, No. 2, Feburary 1963, pp. 73-82.

b. Cox, J. D., "Forecasting the Freezing Level Objectively as an Aid in Forecasting the Level of Icing", ESSA, Weather Bureau Technical Note 23, Fcst-4, Notes to Forecasters No. 4, Weather Bureau, December 1965.

c. Hanson, D. M., et al., "Procedures for Forecasting Clear Air Turbulence", OFDEV Technical Note No. 5, USWB, January 1962.

d. Harrison, H. T., and Sowa, D. F., "Mountain Wave Exposure on Jet Routes of NWAL and UAL", United Air Lines Meteorology Circular No. 60, February 1, 1966.

e. Sorenson, John E., "Synoptic Patterns for Clear Air Turbulence", United Air Lines Meteorology Circular No. 56, December 1962.

6. Depiction.

6.1 Fronts. Surface fronts are depicted according to the symbols shown in appendix 2, and coded using the last 3 characters ($F_tF_iF_c$) of the Frontal Group in the Abridged United States Weather Code (appendix 3).

6.2 Isobars. These are drawn as solid lines at 8 mb intervals with dashed lines at 4 mb intervals added to define the pattern in areas of weak pressure gradient. Isobars are drawn on the 24-hour prognoses made from 0000Z and 1200Z initial data only.

6.3 Pressure Centers. These are indicated by dots with the conventional "H" for high and "L" for low, labeled in millibars by 2-digit numbers (hundreds and thousands omitted). The instantaneous direction of motion is indicated by an arrow (to 36 compass points) labeled with speed in knots (STNRY indicates stationary), valid for the time of the prognosis only.

6.4 Precipitation. Forecast areas are depicted with the format described in appendix 27.

6.5 Clouds. Areas of broken or more low clouds (bases at or below 5,000 feet above ground) are enclosed by a small-scalloped line; and of middle clouds (bases between 5,000 and 25,000 feet above ground), by a large-scalloped line. In practice, both middle and high clouds directly associated with large scale weather systems are forecast. Areas of jet stream cirrus, even below 25,000 feet, usually are forecast on the High Level Significant Weather Prognosis (Chapter 6, Chart UP-11).

6.6 Fog and Stratus. Extensive areas of fog or low stratus, not associated with large scale weather producing systems (such as valley fog in California), are depicted by hatching without enclosing boundaries.

6.7 Freezing Level. The lowest forecast freezing level is depicted by a heavy solid line for the surface intersection (32° F) and by dashed lines at 4,000 foot intervals in the free atmosphere beginning with 4,000 feet MSL. The surface intersection and 4,000 foot contour are terminated at the eastern edge of the Rocky Mountain massif at the 4,000 foot smoothed terrain level.

6.8 Turbulence. Points of moderate or greater turbulence, not associated with thunderstorms, are indicated by the turbulence symbols, for moderate and for severe.

SP-5; PROGNOSIS OF PROBABILITY OF 0.01" PRECIPITATION IN 12 HOURS

Issued every 12 hours, map scale 1:25 million, the area covered is the United States and that portion of Canada south of 49° N, and west of the northern tip of Maine.

Description

1. With Prog Package A (late night in EST) for the 12 hour periods ending 0000Z in the evening, 1200Z the next morning, 0000Z the evening of the next day and 1200Z two days hence.

2. With Prog Package B (mid-afternoon in EST) for the 12 hour periods ending 1200Z the next morning, 0000Z of the evening of the next day, 1200Z of the morning of the second day, and 0000Z of the evening of the second day.

Forecast Procedures

1. NUMERICAL GUIDANCE AVAILABLE:

   Surface 24, 36, and 48 hour prognoses (see chart SP-3) form the basis for these prognoses.

2. OTHER TOOLS AVAILABLE:

   Essentially, the forecast product results from an evaluation of expected distributions of vertical motion and moisture fields, and their interactions. The principal tools used are the same as those used in preparation of quantitative precipitation forecasts (see chart SP-6), plus the following:

   a. Synoptic climatology of precipitation as described in References (1, 2, 3, 4).

   b. Evaluation of the PEP Model (UP-3) output in terms of probability. This model has been in operation since January 2, 1967, and sufficient statistics now are available to be of value to the forecaster in obtaining rough probability estimates from saturation-deficit forecasts.

   c. Evaluation of the quantitative precipitation forecasts in terms of probability. Verification statistics show that in winter the the area within the 12 hour 0.50 of an inch isohyet (as shown in the Primary and Afternoon quantitative precipitation forecast packages) has an 85 to 90% probability of receiving 0.01 of an inch of precipitation in that 12 hour period; in summer the probability is approximately 70%.

3. PREPARATION:

The general philosophy of preparation is to interpret observational, numerical, and other objective and semi-objective aids in terms of point probability occurrence of 0.01 of an inch precipitation during specified 12 hour intervals. The final product represents a subjective evaluation of a great wealth of direct and indirect background information.

Preparation of Actual Fax Chart

First estimates of probability are entered on the working chart about 2 hours before scheduled fax tranmission time. These first estimates give considerable weight to continuity of the probability forecast made 12 hours previously. Alterations and modifications of first estimates are made as numerical guidance becomes available, and as the on-time precipitation prognoses are completed (see chart ST-3).

REFERENCES:

1. Fawcett, E. B., and Saylor, H. K., "A Study of the Distribution of Weather Accompanying Colorado Cyclogenesis", Monthly Weather Review, Volume 93, No. 6, June 1965, pp. 359-367.

2. Jorgensen, D. L., "A Computer Derived Synoptic Climatology of Precipitation from Winter Storms", Journal of Applied Meteorology, Volume 2, No. 2, April 1963, pp. 226-234.

3. Klein, W. H., "Application of Synoptic Climatology and Short-Range Numerical Prediction to Five-Day Forecasting", Research Paper No. 46, Weather Bureau, June 1965.

4. Weather Bureau, "A Synoptic Climatology of Precipitation From Upper Lows for Intermountain Areas of the West", Report No. 1, Techniques Development Laboratory, July 1965.

5. Younkin, R. J., LaRue, J. A., and Sanders, F., "The Objective Prediction of Clouds and Precipitation Using Vertically Integrated Moisture and Adiabatic Vertical Motions," Journal of Applied Meteorology, Volume 4, No. 1, February 1965, pp. 3-17.

6. Kulawiec, M. H., "Local Cloud and Precipitation Forecast Method (SLYH)", Technical Note 13, Fcst-2, Notes to Forecasters, No. 2, Weather Bureau, September 1965.

D e p i c t i o n

The first panel, the forecast for the first 12-hour period, contains only the 50% isopleth, drawn as a solid line with shading towards the area of greater than 50% probability. On the remaining three panels, probability isopleths are drawn as solid lines at 20% intervals

for even values with intermediate odd-valued isopleths at 10% intervals drawn as dashed lines to define the pattern where the gradient of probability is weak. All probability isopleths are labeled in tens of percent.

The charts are read as follows: all points between 10% interval isopleths and along the lower valued of the two isopleths are given the probability percentage of the lower-valued isopleth. For instance, all points along the 30% line and in the area to but not including the 40% line have a value of 30%. In regions where the intermediate isopleths are not drawn, it is necessary to interpolate linearly between the even valued isopleths to estimate the position of the odd-valued isopleth.

(Probability forecasts are made to the nearest 10%; therefore, after rounding off, a value of 10% represents the range 5-14%; 20%, the range 15-24%; 30%, the range 25-34%; and so on. The isopleths are drawn at the lower limit of the probability range--the 10% isopleth at the 5% value, the 20% isopleth at the 15% value, the 30% isopleth at the 25% value, etc. Therefore, all points between isopleths and along the lower-valued isopleth have values in the range represented by the assigned percentage of the lower probability isopleth. For instance, every point along the 30% isopleth and between the 30% and 40% isopleths has a value in the range 25-34%, and, after rounding off to the nearest 10%, is assigned a value of 30%.)

SP-6; QUANTITATIVE PRECIPITATION FORECASTS (QPF)

Issued on facsimile on a 1:25 million base chart for the United States and that portion of Canada south of 49° N and west of the northern tip of Maine, 4 times daily in various formats and durations for facsimile transmission plus once daily for teletype transmission.

Description

1. FACSIMILE TRANSMISSION:

   a. A preliminary (late night EST) forecast for the 24 hour period ending at 1200Z the next day. The 24, 36, and 48 hour surface prognoses (see chart SP-3) are the basis for this forecast.

   b. A primary (early morning EST) forecast for the 12 hour period ending at 0000Z in the evening, the 24 hour period ending at 1200Z the next morning, and an outlook for the 24 hours ending two mornings hence. Here, the 30 hour surface prognosis (see chart SP-2) is used to update the previous forecast. At this time, coded groups and a QPF discussion are also sent out on Service C, under the heading FXUS WBC.

   c. A mid-afternoon (EST) forecast for the 12 hour period ending at 1200Z the next morning, and for the 24 hour period ending at 1200Z the second morning. The 24, 36, and 48 hour surface prognoses (see chart SP-3) are the bases for these forecasts. At this time, coded groups and a QPF discussion are sent on Service C, under the heading FXUS WBC.

   d. An evening (EST) check forecast for the 12 hour period ending at 1200Z, the next morning, giving only significant areas of one inch or more. Here, the 30 hour surface prognosis (see chart SP-2) is used to update the previous forecast.

2. TELETYPE TRANSMISSION:

   a. A mid-day forecast for the 18 hour period ending at 1200Z the next morning. Here, the low-level depiction prognoses (see chart SP-4) are used as a basis for the forecast. This forecast is sent as coded groups with a QPF discussion on Service C lines.

   b. Special QPF, between scheduled forecasts, are issued, when necessary, on the RAWARC circuit as coded groups with a discussion.

Forecast Procedures

1. NUMERICAL GUIDANCE AVAILABLE:

   a. The PEP Model (UP-3) numerical cloud, weather and quantitative precipitation forecasts for 12, 24, 36, and 48 hours, which are available prior to the preliminary and mid-afternoon forecasts.

   b. The 6-Layer Model numerical surface and 1000-500 mb thickness forecasts for 24, 36, and 48 hours, which are available prior to preliminary and mid-afternoon forecasts. Reed 1000 mb and thickness forecasts (3) are available from the barotropic run for the other QPF's, and as backup for the 6-Layer Model.

   c. Baroclinic numerical prognoses of 500 mb height and vorticity for 12, 24, and 36 hours, and height only for 48 hours and barotropic height only for 72 hours, which are available prior to preliminary and mid-afternoon forecasts.

   d. Numerical prognoses of 700 mb vertical motion for 6, 12, 24, and 36 hours, which are available prior to preliminary and mid-afternoon forecasts.

2. OTHER TOOLS AVAILABLE:

   a. Essentially, the forecast product results from an evaluation of expected distributions of vertical motion and moisture fields, and their interactions. Net vertical motion is thought of in terms of equivalent barotropic, baroclinic, non-adiabatic and frictional contributions. Special attention is given to large-scale terrain influences. The evaluation of initial conditions depends greatly upon observed conditions, as shown by the surface map; 6 hourly rainfall and snowfall reports; and upper air circulation, moisture and thermal analyses. The basic tool is the surface prognosis. This maintains internal consistency of all Analysis and Forecast Division (A&FD) weather products.

   b. 1000-500 mb thickness prognosis which contains modifications is superimposed on 1000 mb height prognosis, with special attention to warm advection areas (4), which are available prior to preliminary, primary, mid-afternoon and the evening check forecasts.

3. PREPARATION:

   The general philosophy of preparation is to interpret observational, numerical, and other objective and semi-objective aids in terms of precipitation location and amount (see also appendix 20). In essence, these interpretations depend upon personal experience and aptitude, and the experience of others passed along by written and verbal communication. Continuous endeavor is made to maintain continuity with previous QPF issuances. A principal aim is to fore-

cast realistic precipitation patterns.

Preparation of Actual Fax Chart

Reduction from the working charts (1:20,000,000) to fax transmission scale and tracing for fax transmission requires about 30 minutes. Therefore, charts and data received up to approximately 30 minutes before scheduled fax transmission time may be considered, but full consideration and complete incorporation into the forecasts requires a lead-time of at least 60 minutes.

D e p i c t i o n

On Fax Chart:

The product is depicted as forecast isohyets of precipitation in inches and hundredths at set values of 0.25, 0.50, 1.00, 2.00, 3.00, 4.00, 5.00, etc. Alternate forecast isohyets are used when tight gradients may interfere with quality of fax transmission. The one inch isohyet is the smallest forecast value on the evening check forecast.

REFERENCES:

1. Younkin, R. J., LaRue, J. A., and Sanders, F., "The Objective Prediction of Clouds and Precipitation Using Vertically Integrated Moisture and Adiabatic Vertical Motions", Journal of Applied Meteorology, Volume 4, No. 1, February 1965, pp. 3-17.

2. Kulawiec, M. H., "Local Cloud and Precipitation Forecast Method (SLYH)", Technical Note 13 Fcst-2, Notes to Forecasters No. 2, Weather Bureau, September 1965.

3. Reed, R. J., "Experiments in 1000 mb Prognosis", NMC Technical Memorandum No. 26, Weather Bureau, 1963.

4. STAFF, A&FD, "Synoptic Meteorology as Practiced by the National Meteorological Center", The NAWAC Manual, Part II, March 1963, p. 33.

SP-7; HEAVY SNOW GUIDANCE FORECASTS

Issued on a 1:25 million base chart for the United States and that portion of southern Canada south of 49° N and west of the tip of Maine, 4 times daily in various formats and duration for facsimile transmission plus once daily for teletype transmission, unscheduled special transmission coded for teletypewriter transmission on RAWARC circuit.

Description

1. FACSIMILE TRANSMISSION:

   a. A preliminary (late night EST) forecast for the 12 hour period ending at 0000Z that evening. Here, the 24 hour surface prognosis (see chart SP-3) is the basis for the forecast.

   b. A primary (early morning EST) forecast for the 12 hour period ending at 0000Z that evening. Here, the 30 hour surface prognosis (see chart SP-2) is used to update the previous forecast. Comments on heavy snow forecasts are also sent on Service C lines, under the heading FXUS WBC.

   c. A mid-afternoon (EST) forecast for the 12 hour period ending at 1200Z the next morning. The 24 hour surface prognosis (see chart SP-3) is the basis for this forecast. Comments on heavy snow forecast are also sent on Service C, under the heading FXUS, WBC.

   d. An evening (EST) check forecast for the 12 hour period ending at 1200Z the next morning. Here, the 30 hour surface prognosis (see chart SP-2) is used as a basis for the forecast.

2. TELETYPE TRANSMISSION:

   a. A mid-day check forecast for the 12 hour period ending at 0600Z that night. The 12 and 24 hour surface prognoses (see chart SP-4) are the basis for this forecast. The forecast is also sent as coded groups, with a discussion on Service C lines, under the heading FXUS WBC.

   b. Special heavy snow forecasts (between scheduled forecasts) are issued to update regular guidance during important snowfall situations. These are coded with discussions, and sent on the RAWARC lines.

Forecast Procedures

1. NUMERICAL GUIDANCE AVAILABLE:

   a. The PEP Model (UP-3) numerical cloud, weather and quantitative precipitation forecasts for 12, 24, 36, and 48 hours, which are available prior to the preliminary and mid-afternoon forecasts.

   b. The 6-layer[1] (SP-1) numerical surface and 1000-500 mb thickness forecasts for 24, 36, and 48 hours, which are available prior to preliminary and mid-afternoon forecasts. Reed 1000 mb thickness forecasts also are available from the barotropic run for the other QPF's.

   c. 6-layer[1] numerical prognoses (see UP-2 and UP-8) of 500 mb height and vorticity for 12, 24, and 36 hours, which are available prior to preliminary and mid-afternoon forecasts.

   d. Numerical prognoses of 700 mb vertical motion, 6, 12, 24, and 36 hours, which are available prior to preliminary and mid-afternoon forecasts.

2. OTHER TOOLS AVAILABLE:

   a. Essentially, the forecast product results from an evaluation of expected distributions of vertical motion and moisture fields, and their interactions. Net vertical motion is thought of in terms of equivalent barotropic, baroclinic, non-adiabatic and frictional contributions. Special attention is given to large-scale terrain influences. The evaluation of initial conditions depends greatly upon observed conditions, as shown by the surface map; 6 hourly rainfall and snowfall reports; and upper air circulation, moisture and thermal analyses. The basic tool is the surface prognosis. This maintains internal consistency of all Analysis and Forecast Division weather products.

   b. 1000-500 mb thickness prognosis which contains modifications is superimposed on 1000 mb height prognosis, with special attention to warm advection areas (4), which are available prior to preliminary, primary, mid-afternoon and evening check forecasts.

3. PREPARATION:

   In addition to the tools normally used in forecasting quantitative precipitation, (see also appendix 20) other tools are used to limit forecast heavy snow to areas with favorable tropospheric thermal properties (5,6,7,8). Heavy snow is defined (for these forecasts) as snowfall of 4 inches or more in the specified 12 hour periods.

[1] Reed and 3-layer models used as backup.

A principal aim is to forecast realistic heavy snowfall patterns, although intentionally there is some tendency toward overforecasting areal extent as an alerting mechanism to field forecasters.

Heavy snow forecasts are not issued for the high Sierras, higher mountain passes and mountain tops, unless they are included as a part of a general snow area for the lower, more inhabited areas.

Lake-effects are considered in forecasting heavy snow for the Great Lakes Region, but areas usually are not outlined except when synoptic conditions combine with lake-effects to increase the likelihood of more general heavy snowfall.

The general philosophy of forecast preparation is to interpret observational, numerical, and other objective and semi-objective aids in terms of heavy snow occurrence and location.

Preparation of Actual Fax Chart

Complete consistency is maintained with the quantitative precipitation forecast for the same period. Therefore, final decision as to location and extent of heavy snow is not made until the corresponding period QPF is completed. The normal assumption is that approximately 0.25 of an inch of precipitation is the minimum amount necessary for heavy snow. The heavy snow forecast is traced for fax transmission about 15 minutes before scheduled transmission.

REFERENCES:

1. Younkin, R. J., LaRue, J. A., and Sanders, F., "The Objective Prediction of Clouds and Precipitation Using Vertically Integrated Moisture and Adiabatic Vertical Motions", Journal of Applied Meteorology, Volume 4, No. 1, February 1965, pp 3-17.

2. Kulawiec, M. H., "Local Cloud and Precipitation Forecast Method (SLYH)", Technical Note 13, Fcst-2, Notes to Forecasters No. 2, Weather Bureau, September 1965.

3. Reed, R. J., "Experiments in 1000 mb Prognosis", NMC Technical Memorandum No. 26, Weather Bureau, 1963.

4. STAFF, A&FD, "Synoptic Meteorology as Practiced by the National Meteorological Center", The NAWAC Manual, Part II, March 1963, p. 33.

5. Fawcett, E. B., and Saylor, H. K., "A Study of the Distribution of Weather Accompanying Colorado Cyclogenesis", Monthly Weather Review, Volume 93, No. 6, June 1965, pp. 359-367.

6. Penn, S., "The Prediction of Snow vs. Rain", Forecasting Guide No. 2, Weather Bureau, November 1957.

7. Wagner, A. J., "Mean Temperature from 1000-500 mb as a Predictor of Precipitation Type", Bulletin of the American Meteorological Society, Volume 38, No. 10, December 1957, pp. 584-590.

8. Younkin, R. J., "1000-850 mb and 850-700 mb Thickness Precipitation Type Relations" Unpublished Research Report U. S. Weather Bureau, Knoxville, Tennessee, 6 pp., 1957. Available in the Weather Bureau Library.

9. Goree, P. A., and Younkin, R. J., "Synoptic Climatology of Heavy Snowfall Over the Central and Eastern United States", Monthly Weather Review, No. 11, November 1966, pp. 663-668.

Depiction

The heavy snow isopleth labeled as 4" appears as a solid line on the heavy snow guidance chart and as a dashed line when superimposed on the QPF guidance chart.

SP-8; 24-HOUR TEMPERATURE PROGNOSIS

Issued for temperatures valid during 12 hour periods each terminating 24, 36, 48, and 60 hours in advance and showing significant isotherms (i.e., 10° F interval in winter and 5° F interval in summer) and significant changes (i.e., $\geq$10° F in winter and $\geq$ 5° F in summer), presented on four 1:25 million panels, each covering the United States and that portion of southern Canada south of 49° N, and west of the northern tip of Maine, transmitted twice daily.

Description

These prognoses are cycled twice daily, as part of:

1. Prog Package A - from 0000Z (early morning, EST) showing:

   today's maximum,
   tonight's minimum,
   tomorrow's maximum, and
   next night's minimum.

2. Prog Package B - from 1200Z (mid-afternoon, EST) showing:

   tonight's minimum,
   tomorrow's maximum,
   tomorrow night's minimum, and
   next day's maximum.

These prognoses are also sent on the National Facsimile Circuit with the 60 hour prognosis replaced by the evening check heavy rain or snow forecast (see charts SP-6 and 7).

Forecast Procedures

1. NUMERICAL GUIDANCE AVAILABLE:

   a. Forecast Model

      Two sets of statistical regression equations, one for minimum and one for maximum temperatures, have been developed by the Techniques Development Laboratory in the Systems Development Office of the Weather Bureau. These will be referred to hereinafter as Klein II equations. Klein II temperature forecasts and resulting 24 hour changes are made twice daily, on the NMC computer as part of the RADAT forecast (barotropic mesh) run which begins at 0130Z and 1330Z. These equations use forecast 500 mb heights and 1000-500 mb thickness obtained from the barotropic and Reed models (see charts UP-1 and SP-1) progs. The observed maximum and minimum temperatures* used to start the forecasts are obtained by automatic decoding of surface reports on NMC's IBM 360 and processed in the 7094 computer systems.

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*These are 12 hour observed maximum and minimum temperatures (see chart AC-4).

b. Data Used for Derivation of Equations:

Fifteen years (1948-1963) of maximum and minimum temperatures at 119 United States and Canadian stations (see appendix 21), plus 1000-700 mb thicknesses and 700 mb heights, at NWP grid points, were used to derive the basic forecast equations. Five years of data (1955-1960) were then used to develop a relation between 500 mb heights and thicknesses and 700 mb heights and thicknesses. Also, in the derivation of the equations, a 12 hour lag was used for upper-air parameters and either 12 or 24 hour lag for the previous maximum and/or minimum temperatures.

In an attempt to get more information on seasonal variations into the equations, the following parameters are also made available to be used in deriving the equations:

1) The number of the day of the year (i.e., 1 to 365)
2) The sine function of the day of the year
3) The cosine function of the day of the year
4) Twice the sine function in "2"
5) Twice the cosine function in "3"

} Considering the year as having roughly 360 degrees (or days).

These functions represent (in increasing "order") Fourier components of the seasonal variation. Experience has indicated that much information on seasonal variation is already contained in the variation of the first term of the equations, since equations are derived for six, two-month periods. Of the terms listed above, all seem to account equally well for most of the seasonal variation or change in slope of the seasonal curve. Therefore, only the day-of-the-year term has been included in later versions (after September-October) of the equations.

c. Method Used in Derivation of Equations

Separate equations for maximum and minimum temperatures are being derived in two-month increments (beginning with September-October) at the 143 stations, shown in appendix 21. The method used is a modification of the step-wise multiple regression technique known as the screening procedure.

In this procedure, the two most significant of the set of available parameters (see paragraph 2 above) are first selected. The more significant of these two is then used to derive a one-parameter equation. The other parameter is tossed back into the "hopper" and the next two most significant parameters are selected. The more significant of these two is combined with the original parameter to form a new regression equation, and so on, until less than a 2% increase in reduction of

variance is explained by the last two parameters selected. At this point, no new parameters are selected and the forecast equation is complete.

2. OTHER TOOLS AVAILABLE:

The A&FD temperature forecaster has the following tools available to prepare his forecast:

a. The complete set of Klein II temperature and temperature-change forecasts out to 60 hours.

b. The package of initial, 12, 24, and 36 hour barotropic prognoses (see UP-1) and Reed prognoses (see SP-1).

c. The A&FD 24, 36, and 48 hour surface prognoses, (see chart SP-3) and accompanying 500 mb prognoses (see chart UP-4).

d. A file of observed 24 hour maximum and minimum temperatures.

e. The latest surface, cloud and weather, and upper-air analyses.

3. PREPARATION:

The temperature forecaster's job is twofold:

a. To eliminate systematic errors in the Klein II forecasts.

b. To present temperature and temperature change forecasts which are consistent with other prognoses (e.g., surface, cloud, and weather) in Prog Package A and B (see discussion with chart SP-3).

The primary effort by the forecaster is directed toward the temperature forecast. The 24 temperature changes which are also depicted on the fax chart are obtained from a smoothed graphical subtraction of the forecast isotherms.

Limited experience, at NMC, with use of Klein II equations, indicates their most systematic error is lack of amplitude in forecasts of temperature change particularly beyond 24 hours. In areas where large changes occur less frequently (i.e., southern and western United States), the Klein II system shows quite a bit of skill.

Depiction

On Fax Chart

1. Each panel depicts a minimum or maximum temperature valid during the 12 hour period ending at the time and for the type (maximum or minimum) of temperature shown on the label. These are considered as the 12 hour maximum or minimum, to be consis-

tent with the observed temperatures (see chart AC-4) which are used in making the Klein II forecast.

2. Each panel also depicts a 24 hour temperature change ending at the time and for the type (maximum or minimum) of temperature shown on the label.

3. In winter, the basic interval of depiction is 10°F, with 5° interval added where necessary to define the pattern. In summer (May through August) the basic interval is 5°F. 32°F is always depicted in lieu of 30°. All basic isotherms are depicted as solid lines done by hand. Temperature change isopleths are depicted as dashed lines and are superimposed on the forecast isotherms. A zero temperature change isopleth is inserted for clarity over the intermountain west. The isopleths are drawn by hand.

SP-9; SEVERE WEATHER OUTLOOK (WWUS-1) MKC

For the contiguous United States two panel 1:20 million scale transmitted once daily at 1200Z.

Description

One panel depicts areas of general thunderstorms and areas of severe thunderstorms for the 24 hour period from issuance time (see appendix 22). Second panel is a prognosis of the axis of the strongest low level wind (low level defined as not above 5000 feet), the maximum wind at upper levels (range 25,000 to 45,000 feet) and the lifted index, a measure of stability similar to the Showalter Index (see appendix 23). This prognosis verifies 12 hours from transmission time (0000Z). Prognosis based on 0000Z upper air data and 0600Z surface data, revised and updated by 0600Z upper wind data and 0900Z surface data as required.

In addition a written Convective Outlook (AC) is also transmitted over Service A at 1140Z.

During the period September 1 to January 31, the WWUS-1 is transmitted only when severe thunderstorms are expected. Otherwise, the notation "No Severe Thunderstorms Expected" appears on the 0845Z transmission of the radar summary chart (ADUS).

Forecast Procedures

1. NUMERICAL GUIDANCE:

   Extensive use is made of NMC products received on the National and Forecast Center Facsimile Networks. With the large scale flow pattern established, the SELS forecaster reverts to specially analyzed charts to locate and prognosticate embedded small scale systems for periods of 12, 18, and 24 hours. These are hand-processed.

2. TOOLS AVAILABLE:

   a. Additional prognoses to establish the stability field and its trend are made. This involves a consideration of both the lower and upper level thermal and moisture patterns and their intensities.

   b. NMC wind progs are adjusted based on 0600Z wind data. These two steps are also hand-processed.

   REFERENCES:

   1. Atlas, David, et al., "Severe Local Storms", Meteorological Monographs, Volume 5, No. 27, September 1963, pp. 141-155.

Philosophy of Forecast

The Severe Thunderstorm Outlook is a pictorial presentation of the written Convective Outlook (AC) transmitted over Service A at 1140Z with the addition of a prognosis of selected parameters verifying at 0000Z. The intent of the Severe Thunderstorm Outlook is to alert all interests concerned, for planning purposes or otherwise, to the possibility of future severe local storm development. It is also an alert to the general areas where specific severe weather watches and/or forecasts might be issued later in the day. The NMC Guidance received, the additional hand-processing performed and the thought processes executed by the SELS forecaster are directed toward the written AC. The pictorial presentation follows quite readily.

Depiction

A legend appears on each panel explaining the depiction. Additional clarification:

1. Lifted Index lines are drawn for each 2° C below 0° C, starting with 0° C.

2. The tornado area depictor (cross-hatching) appears only when a tornado watch is in effect at transmission time.

3. The word FEW* and abbreviations SCTD and NMRS refer to the corresponding percentages of the area covered by such thunderstorm activity during the whole 24 hour outlook period, or during the time period indicated when applicable, not any one particular time. The abbreviation ISOLD is used to indicate minimal activity.

4. When severe thunderstorms are forecast to develop along an instability line, the appropriate symbol and beginning time are entered. Ending times are inserted when practical.

*FEW - up to 15% coverage
SCTD - 16 to 45% coverage
NMRS - more than 45% coverage

SP-10; SEA SURFACE WAVE PROG

Description

12- and 36-hour prognoses twice a day from 0000Z and 1200Z initial data, produced by computer from a model developed at the U. S. Navy Fleet Numerical Weather Facility (FNWF) at Monterey for the Atlantic north of 30° N latitude on a 1:30 million scale.

Data Inputs

This program utilizes:

1. History tapes containing the u/v components of surface geostrophic wind from -18 to +48 hours for each synoptic time.

2. A ship's data list containing all collected ship reports sorted by time (last time first order) with all OSV reports held in a special data reserve.

3. A history tape of wind wave height, direction, and period from -84 hours to +48 hours for each synoptic time.

Philosophy of Analysis

The surface wind directions are corrected for cross contour flow and stability in regard to direction and speed. The duration is determined with directional limits set at $\pm$ 22°. The maximum duration is limited to 18 hours according to the French school which considers all seas to be fully developed after that time period. The significant wave height and period are then computed, for the analysis and prognosis times per synoptic period, from the following formulae:

$$H_{1/3} = K_1 V^2 D + K_2 V$$

$$T_{1/3} = V(K_3 + K_4 D) + K_5$$

where V is the corrected wind speed, D is the duration, and K_1 through K_5 are empirical constants. An additional correction and limitation for fetch length, offshore flow, and points designated in the FNWF land/sea/ice table is made at this time to limit wave height development.

At this point, a difference field between the wind wave analysis and reported ship heights is formed utilizing oldest reports first (within 9 hours) and superimposing, sequentially, ship reports until all on time reports have been considered. In this operation, differences in excess of 22 feet between the FNWF analysis and reported ship observa-

tions, and ship reports that show a variance greater than 20 feet between their reported wind wave and swell groups are rejected. Finally, all OSV and other designated ship reports are placed into the difference field to give maximum weight to these quality reports through last pass insertion. This difference field is smoothed and added to the FNWF analysis, 12 hour and 24 hour prognosis wind wave fields (different smoothing factors and smoothing passes are utilized in the 12 and 24 hour prognoses).

The swell height, direction and period are determined from the historical wave fields with only waves 24 hours old and heights greater than 6 feet considered for swell generation and decay. Travel distance and spreading are computed, and swell heights and periods are then determined from:

$$H_D = H_F\left(\frac{T_D}{T_F}\right)^{-2.81}$$

$$T_D = \left(T_F^2 + \frac{C_2 d}{\bar{m}}\right)^{1/2}$$

H_D height at end of decay

T_D period at end of decay

H_F initial height

T_F period

d travel distance

$\bar{m}$ mean map factor along decay path

C_2 empirical constant

For practical purposes, only the highest swell (with its direction and period) for a particular grid point is retained.

The combined wave analysis/prognosis is formed from the wind wave and swell analysis/prognosis utilizing the following formula:

$$CH = (WH^2 + SH^2)^{1/2}$$

except where WH is greater than 22 feet, CH = (WH). The direction and period of the highest wind wave or swell is retained as the combined direction and period.

Depiction and Coding

Height contours in feet for the highest one-third of the waves are depicted by solid lines at 4-foot intervals labeled by hand. Centers of maximum height and areas of minimum height are hand-labeled as max and min respectively. Arrows indicate direction of wave movement.

UP-1; FOUR-PANEL NWP BAROTROPIC PROGNOSIS

Includes an initial analysis with 12-, 24-, and 36-hour prognoses of 500 mb height contours, and isopleths of absolute vorticity, issued twice daily from 0000Z and 1200Z UX selected level data collections. Each panel covers the North American area on a 1:30 million scale chart (see appendix 24).

The Equivalent Barotropic Model

More detailed information on the equivalent barotropic model is available in the following references:

REFERENCES:

1. STAFF, A&FD, NAWAC Manual Part II, Chapter I (starting on page 7).

2. Charney, J. G., "On a Physical Basis for Numerical Prediction of Large-scale Motion in the Atmosphere", Journal of Meteorology, Volume 6, No. 6, December 1949. pp. 371-385.

3. Roberts, C. F., "Present and Future Operational Numerical Prediction Models", ESSA Technical Note 16 Fcst-3, October 1965.

IMPORTANT FACTS:

1. Definition of the Equivalent Barotropic Atmosphere

In an equivalent barotropic atmosphere, the absolute vorticity is conserved at that level at which the actual wind speed is equal to the pressure-averaged wind speed. A mathematical expression (or a prognostic equation) which expresses the above relation is called a model because it resembles or approximately describes the actual atmosphere. Thus, the local change of vorticity + advective change of vorticity = 0,

$$\text{or} \quad \frac{\partial \zeta}{\partial t} + \bar{u}\frac{\partial \zeta}{\partial x} + \bar{v}\frac{\partial \zeta}{\partial y} = 0$$

is the simplest form of the Barotropic Model. The vertically averaged winds ($\bar{u}$ and $\bar{v}$) apply at about 500 mb (called the level of non-divergence).

2. Implied Vertical Motions

According to the definition of an equivalent barotropic atmosphere:

a. The assumed wind profile most often resembles that associated with the middle-latitude polar jet at about 250 mb, and

b. The sign of the large-scale divergence must change at least once in the vertical between the surface and top of the atmosphere.

c. Therefore, with positive vorticity advection (i.e., vorticity values increasing upstream) ahead of a trough, large-scale convergence occurs below, and divergence above 500 mb, producing upward vertical motion at that pressure surface. The opposite divergence pattern produces downward motion behind a trough.

d. Also, in the equivalent barotropic atmosphere, troughs and ridges have no slope in the vertical, since pressure and thermal patterns are in phase.

3. Engineering of the Equivalent Barotropic Model

Several years of operational experience, with the barotropic model, have produced the following terms engineered to correct systematic errors in the forecast:

a. Helmholtz term which reduced large height errors resulting from retrogression of the very long atmospheric waves (numbers 1, 2, and 3).

b. Mountain correction term which adds vertical motions (divergence) at 500 mb due to flow over the smoothed mountain ranges used in the model.

c. Friction correction term which adds vertical motion (divergence) at 500 mb, proportional to the average roughness of the terrain over which the air is flowing.

Both the mountain and friction correction terms depend on an accurate forecast of the low-level flow (e.g., at 850 mbs). At present, the barotropic forecast is meshed with an 850 to 500 mb thickness forecast designed to produce a low-level wind forecast for use in these two terms. For a detailed description of this meshed barotropic, see:

REFERENCES:

1. Gustafson, A. F., "Mesh Model 1964", NMC Office Note No. 24.

2. Roberts, C. F., "Present and Future Operational Numerical Prediction Models", ESSA Technical Note 16 Fcst-3, October 1965.

Derivation and Depiction

The "Mesh Model" barotropic forecast is run from an automatic data processing (ADP) and computer analysis of the UXNA 850 mb and 500 mb selected level data, and begins at 1 1/2 hours after observation time. The ADP and analysis procedures are described under chart UA-1.

1. Prognostic Contours

The stream function, the basic parameter, is forecast at the NWP network of grid points spaced about 180 nautical miles apart (appendix 11). These are converted to grid point heights by inversion of the balance equation. The location of points, 1/8" apart on the map scale, along each standard contour is determined by quadratic interpolation from grid point heights.

2. Prognostic Absolute Vorticity

The relative vorticity is calculated at each grid point from the Laplacian[1] (∇^2) of the forecast stream function. The Coriolis Parameter is then added. Next, points along the isopleths of absolute vorticity are interpolated for every 1/8" from grid point values and smoothed[2]. Note that vorticity values are not calculated directly from heights, and are smoothed separately from heights. Therefore, calculation of vorticity values from contours will not necessarily duplicate values drawn on the chart. Also vorticity values are directly dependent on grid interval used in their computation.

3. Depiction

Isopleth location points for both height contours and absolute vorticity are traced out by the Curve Follower directly on the sectional facsimile charts. Height contours are drawn as dashed lines at

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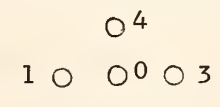
[1] In finite differences this means:



taking the sum of the values at grid points 1, 2, 3, and 4, and subtracting 4 times the value at 0. $\frac{(1+2+3+4-4(0))}{\Delta \text{ grid interval}}$

[2] The initial vorticity isopleths are obtained in a similar manner from the initial stream function field derived from the analyzed balanced height field.

60 meter intervals, hand labeled in decameters. High and low centers are indicated by +, machine labeled in decameters.

Absolute vorticity isopleths are drawn as solid lines at intervals of 2×10^{-5} sec^{-1}, hand labeled in tens and units of 10^{-5} sec^{-1}. Centers of maximum and minimum absolute vorticity are indicated by +, machine labeled in tens, units and tenths of 10^{-5} sec^{-1}.

UP-2; FOUR-PANEL NWP BAROCLINIC PROGNOSIS

Includes an initial analysis with 12-, 24-, and 36-hour prognoses of 500 mb contours and isopleths of vertical velocity. Issued twice daily based on data available 3+25 hours after 0000Z and 1200Z upper-air observation times. Each panel covers the North American area on a 1:30 million scale (see appendix 24).

The 6-Layer (PE) Numerical Prediction Model

The prognostic equations used in the model are the original Newtonian equations of motion which balance accelerations (along any coordinate) with the forces acting in that direction.

For instance, when pressure is the vertical coordinate, the first equation of motion becomes:

$$\frac{\partial u}{\partial t} + V.\nabla u + \omega \frac{\partial u}{\partial p} \quad \text{(total acceleration in x-direction)} =$$

$$fv \text{ (coriolis force in x-direction)} - \frac{\partial gz}{\partial x} \text{ (pressure force}$$

$$\text{in x-direction)} + F_x \text{ (frictional forces in x-direction).}$$

The general equations are capable of forecasting several types of wave motion in a fluid such as the atmosphere (e.g., sound waves, gravity waves, Rossby waves).

In the 3-level filtered model, the Newtonian equations are combined to form a prognostic vorticity equation which circumvents some of the mathematical and physical problems that seemed insurmountable a few years ago in operational NWP. In both models, motion of sound waves is eliminated by use of the hydrostatic approximation. In the filtered model, gravity waves are eliminated by use of the balanced or non-divergent wind. Gravity waves are allowed to propagate in a controlled manner in the primitive equation model. Therefore, the primitive equation model must be integrated in much shorter time steps than the filtered model (i.e., 10 minutes versus 1 hour). As a result, the present PE model requires about 60 minutes (including initialization) to run out to 36 hours on the CDC 6600, in contrast to about 50 minutes for the 3-level model on on the IBM 7094 II.

IMPORTANT FACTS:

1. Basic equations used

   a. The two horizontal equations of motion, used to forecast u- and v-components of the wind (in the x- and y-directions on the NWP grid of appendix 11).

b. The hydrostatic equation and the equation of state which relate pressure, temperature, and height.

c. The thermodynamic energy equation used to forecast temperature.

d. The equation of mass continuity which relates mass divergence and vertical motion, and is used to forecast vertical pressure change in this model.

This system of equations is complete; that is, it allows all dependent variables in the system to be forecast. The primary forecast variables are the wind, temperature and pressure.

2. The vertical structure

The equations are written in terms of a special vertical coordinate sigma (σ). The sigma system is based on pressures at three material surfaces: the smoothed profile of the earth's surface which approximates the real topography, p*; the tropopause, p**; and a pressure level in the lower stratosphere above which the atmosphere is assumed to have no meteorological significance, p_o. The troposphere is subdivided into a boundary layer and three other layers and the stratosphere into two layers. The value of σ at any given pressure level is determined in the boundary layer, the troposphere and the stratosphere from

$$\sigma = \frac{p - p_u}{p_l - p_u}$$

where the subscripts indicate upper and lower. The vertical structure is illustrated schematically in appendix 39.

3. Initialization (15 minutes on CDC 6600)

To obtain a set of initial data for the PE model, NMC analyzes data over the Northern Hemisphere as far south as 10-15° north latitude.

a. Sea-level pressures and surface temperatures, from which 1000 mb heights are computed.

b. Heights and temperatures at nine other constant pressure surfaces, 850, 700, 500, 400, 300, 250, 150, and 100 mb. (Temperatures at 1000 mb are computed.)

c. Pressures and temperatures at the tropopause.

Pressures and heights for the σ-surfaces (including pressures for the earth's surface for which height is given by the smoothed profile) are interpolated. Mean potential temperatures are computed from the hydrostatic equation and mean non-divergent wind components are obtained from a solution of the balance equation for each

of the σ-layers.

4. Computer forecast procedures

a. The forecast equations applied to the initial data compute 10-minute tendencies of mean wind components, u and v, and of mean potential temperature and pressure difference between σ-surfaces for each of the six layers of the model. The tendencies added to the initial data produce a new set of values valid ten minutes later to which the forecast equations are again applied. The process is repeated for the 216 time steps out to the 36-hour forecast.

b. Large-scale skin friction, based on Cressman's hemispheric drag coefficient (2), is introduced in the Boundary Layer. It has the most noticeable effect of keeping low-pressure centers near the earth's surface from becoming too deep during the forecast.

c. Solar heating and general radiative cooling are included for all layers in the model. The boundary layer is heated over the oceans when the mean potential temperature is lower than sea surface temperatures as indicated by daily Monterey analyses, and cooled at night over snow surfaces as indicated by satellite photographs. Feedback of latent heat of condensation from the Primitive Equation Precipitation (PEP) Model is included also.

5. Derivation of output

a. Initial 500 mb heights come from the 10-level analysis program described under charts UA-2 and UA-3

b. 500 mb prognostic heights at each NWP grid point (appendix 11) are computed from

1) interpolation of the prognostic mean potential temperatures applying at the midpoints of the σ-layers (3) and (4) (appendix 39) and

2) prognostic heights and pressures at the σ-surfaces above or below 500 mb

using the hydrostatic equation and assuming a linear variation of potential temperature with a function of pressure which is the ratio of absolute temperature to potential temperature.

$$\pi = \frac{T}{\theta} = \left(\frac{p}{1000}\right)^{\frac{R}{c_p}}$$

c. Initial vertical velocity is zero at all levels in the PE model because the initial balanced wind field is non-divergent. However, divergent components of the wind build up rapidly as the numerical prediction progresses. Vertical velocity forecasts may be read out beginning with the third hour of computations.

d. Prognostic vertical velocities are derived as follows:

1) Vertical velocities are computed on the σ-surfaces from the mean u- and v-components of the wind in the σ-layers and the pressures on the σ-surfaces by use of the continuity equation and the condition of no mass transport through material surfaces. Mean values applying at the midpoints of the σ-layers are obtained at each grid point by averaging the values of vertical velocity on the bounding σ-surfaces.

2) Vertical velocities may be interpolated to any constant pressure surface by assuming a linear variation with respect to the function of pressure

$$\pi = \left(\frac{p}{1000}\right)^{\frac{R}{c_p}}$$

Transmitted vertical velocities are the values interpolated to 700 mb.

3) Vertical velocities are averaged over twelve 10-minute time steps, one hour before and one hour after valid time, to smooth out the effects of the gravity waves in the model.

REFERENCES:

1. Berkofsky, L., and Bertoni, E. A., "Mean Topographic Charts for the Entire Earth," Bulletin of the American Meteorological Society, Volume 36, No. 7, September 1955, pp 350-354.

2. Cressman, G. P., "Improved Terrain Effects in Barotropic Forecasts," Monthly Weather Review, Volume 88, No. 9-12, September-December 1960, pp 327-342.

Other references which contain similar and/or more detailed information on the primitive equation model:

3. Roberts, C. F., "Present and Future Operational Numerical Prediction Models", ESSA Technical Note 16, Fcst-3, October 1965.

4. Shuman, F. G., et al., "A Multi-Level Primitive Equation Model Suitable for Operational Numerical Weather Prediction", collection of 3 papers, available at NMC, Suitland, Maryland, November 1965.

5. Badner, J., "Performance of the 6-Layer Baroclinic (Primitive Equation) Model", ESSA Technical Memorandum WBTM-Fcst-5, Notes to Forecasters No. 5, September 1966.

6. Snellman, L. W., "Sigma surfaces - a replacement for constant pressure surfaces", Western Region Technical Attachment, May 24, 1966.

7. Snellman, L. W., "The Physics of the NMC Primitive Equation Model", Western Region Technical Attachment, June 7, 1966.

T h e 3-L e v e l B a r o c l i n i c M o d e l
(used as backup for the 6-Layer Model)

More detailed information on the 3-level baroclinic model is available in the following references:

REFERENCES:

1. Cressman, G. P., "A Diagnostic Study of Mid-Tropospheric Development", Monthly Weather Review, Volume 89, No. 3, March 1961, pp 74-82.

2. Cressman, G. P., "A Three-Level Model Suitable for Daily Numerical Forecasting", NMC Technical Memorandum, No. 22, 1963, or

3. Roberts, C. F., "Present and Future Operational Numerical Prediction Models", ESSA Technical Note 16, Fcst-3, October 1965.

IMPORTANT FACTS:

1. Engineering of the Baroclinic Model

Briefly, the baroclinic prognostic equation, or model, includes the terms found in the barotropic model, plus the 3 engineering terms, Helmholtz, mountains, and friction (see description under chart UP-1).

2. Additional Terms

Added ingredients in the Baroclinic model are:

a. Terms in the prognostic equation which account for creation and destruction of vorticity via large-scale divergence, vertical advection of vorticity, and through rapid

changes in vertical wind shear, and the horizontal field of vertical motion (i.e., the so-called "twisting term").

b. Diagnosis, initially and at each time step, of the profile of vertical motion through use of the vertical motion or ω equation.

3. Computer forecast procedures

The 3-level forecast is computed in the following manner:

a. Height values at 850, 500, and 200 mb are used as initial data. The 850 heights are converted to 800 mb heights by a linear interpolation between 850 and 500 mb.

b. A non-divergent wind or stream function field is computed at each forecast level by solution of the balance equation.

c. The vertical-motion (ω) equation is then solved using terrain and friction-induced vertical motions at 1000 mb, and zero at the top of the atmosphere.

d. The resulting vertical motions at 100 mb, 350 mb, 650 mb, and near the earth's surface are used to compute horizontal divergence at the three forecast levels (800, 500, 200 mb) through the equation of mass continuity.

e. These divergences are used to solve the vorticity equation, independently, at each of the forecast levels and thus to compute the vorticity change over a period of one hour.

f. From these vorticity changes, a new stream function field is computed for the next hour at each forecast level (800, 500, and 200 mb), and the forecast proceeds through another cycle.

4. Derivation of output

The automatic data processing (ADP) and analysis used for the 3-level model is described under chart UA-2.

a. The stream function at 500 mb, the basic parameter, is forecast for the NWP network of grid points (appendix 11). The stream function field is converted to 500 mb grid point heights by inversion of the balance equation.

b. Initial and prognostic vertical velocities are computed by the ω-(vertical velocity) equation from:

1) differences in advection of absolute vorticity at 800 and 500 mb and

2) Laplacian of thickness advection in layer 800 to 500 mb.

The computed vertical velocities represent the mean in the layer 800 to 500 mb and apply at the midpoint of the layer, 650 mb.

Depiction of Output

1. Contours

Initial and 12-, 24-, and 36-hour prognostic heights at 500 mb are determined at the network of NWP grid points spaced about 180 nautical miles apart (appendix 11). The location of points 1/8" apart on the map scale along each standard contour is obtained by quadratic interpolation from the grid point heights. The Curve Follower traces out these location points on a 1:30 million scale hemispheric base chart. These contours are then traced ("wheeled")[1] onto the sectional facsimile base chart by hand as dotted lines at 60 meter intervals. Contours are hand-labeled in decameters.

2. Vertical Velocity

Vertical velocities at 700 mb are averaged over twelve consecutive 10-minute time steps--in the 4th and 5th, 10th and 11th, 22nd and 23rd, and 34th and 35th hours of the forecast period. The values of vertical velocity at each grid point, then, are centered at 5, 11, 23, and 35 hours after observation time for the PE Model. Initial 500 mb contours are traced on the 5-hour vertical velocity forecast.

The 3-Level Baroclinic Model furnishes grid point values of vertical velocity for the initial (actually one hour after observation time) and 12-, 24-, and 36-hour prognostic times.

Location points 1/8" apart on the map scale along standard isopleths of vertical velocity are determined by quadratic interpolation from the grid point values. The Curve Follower traces out these location points to draw the isopleths as solid lines at intervals of one microbar per second.[2] (During the months, April-September the interval is .5 microbars per second.) Isopleths are hand-labeled in microbars per second, which may be converted to centimeters per second by multiplying by 1.12 at 700 mb (PE Model) and by 1.19 at 650 mb (3-level model). Positive values indicate upward motion and negative values downward motion. Centers of maximum upward and

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[1] The line is produced by a small hand device containing an appropriately notched wheel 3/4" in diameter.

[2] 1 millibar = 1000 microbars

downward vertical velocities also are interpolated and printed out by the Curve Follower as + labeled in tenths of microbars.

(Comparisons made at NMC have shown that vertical velocities from the 3-level baroclinic model are systematically weaker than those computed manually for the layer 1000-500mb. The normal method uses a moist-adiabatic stability value instead of the climatological value used in the numerical model which does not include the layer below 800 mb where significant temperature advection occurs.)

UP-3; MEAN RELATIVE HUMIDITY FORECASTS

Prepared twice a day from 0000Z and 1200Z data covering the North American area on a 1:30 million scale. Chart consists of four panels including an initial analysis and 12-, 18-, and 24-hour forecasts of the mean relative humidity in layer from surface to near 400 mb.

Initial Analysis

The initial moisture analysis procedure is as follows:

a. The initialization procedure for the PE model provides mean potential temperatures in each σ-layer and pressures on each σ-surface (appendix 39) at each NWP grid point (appendix 11). Prior to the moisture analysis, saturated total precipitable water amounts, W_s, are computed for the lowest three layers of the model from these parameters.

b. All available radiosonde observations are employed for the computation of observed precipitable water surface to 400 mb from the temperature-dewpoint/pressure observations at the sounding sites. This process is described under chart AC-3.

c. All SM coded synoptic surface observation locations in blocks 70-79 (North America and environs) reporting precipitation at or near the station, at observation time or in the past hour, are assigned a mean relative humidity equal to the saturation value. The saturation value has been set at 80% (except 70% May through September) because of observational evidence that precipitation can occur even when parts of the air column are unsaturated. Present weather (ww) code 15, 16, 18, 21-23, 25-27, 29, 58-75, and 79-99 are considered as indicators of precipitation.

   Saturated precipitable water totals at the observation sites, W_s, are determined by bilinear interpolation from the previously computed grid point values. Multiplication by the appropriate saturation mean relative humidity for the season gives the reduced saturated precipitable value for the observation site:

$$\hat{W}_s = .8W_s$$

   The computed precipitable water from the ww group takes precedence over that computed from the radiosonde.

d. Values of "observed" total precipitable water, W, at each grid point are determined from the radiosonde and SM observation point values by the NWP analysis procedure (see chart UA-1).

e. The "observed" precipitable water at each grid point is converted to mean relative humidity by dividing by the reduced saturated precipitation total $\hat{W}_s$, for 80% (or 70%) saturation relative humidity and multiplying by 100:

$$R.H. = 100 \frac{W}{\hat{W}_s}$$

This procedure allows the relative humidities to have the full normal range of 0 - 100%[1].

Numerical Model

The mean relative humidity forecasts are produced by the primitive equation precipitation (PEP) model which is a part of the 6-layer (PE) numerical prediction model (see charts UP-2 and UP-4). Forecasts are made for the lowest three layers of the PE model (appendix 39): the boundary layer and the lower two layers of the troposphere (top about 420 mb).

FORECAST EQUATION

The basic forecast equation for precipitable water is derived from:

1. The moisture continuity equation which, in the σ-system, becomes:

$$\frac{\partial q}{\partial t} = - \mathbb{V} \cdot \nabla q - \dot{\sigma} \frac{\partial q}{\partial \sigma}$$

$$= - \mathbb{V} \cdot \nabla q - \frac{\partial (\dot{\sigma} q)}{\partial \sigma} - q \frac{\partial \dot{\sigma}}{\partial \sigma}$$

where $\dot{\sigma} \equiv \frac{d\sigma}{dt}$, the σ-system vertical velocity equivalent. This equation states that, when moisture is conserved, the local change of specific humidity q is given by the horizontal and vertical advections of specific humidity.

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[1] To reconcile values of initial relative humidity with those on National Facsimile 18 and 81, chart AC-3, multiply PEP relative humidities by 0.8 (except 0.7 May through September).

2. The equation for precipitable water in the σ-system for a layer with upper boundary u and lower boundary l:

$$W = \frac{p_\sigma}{g} \int_{\sigma_u}^{\sigma_l} q \partial\sigma$$

where p_σ is the difference in pressure between σ-surfaces and g is gravity.

The basic forecast equation for precipitable water is developed by differentiating the W equation with respect to time and combining with the moisture continuity equation:

$$\frac{\partial W}{\partial t} = -\frac{p_\sigma}{g} \int_{\sigma_u}^{\sigma_l} \mathbf{V}\cdot\nabla q \partial\sigma + \frac{p_\sigma}{g} \int_{\sigma_u}^{\sigma_l} q \frac{\partial \dot{\sigma}}{\partial\sigma} \partial\sigma$$

$$- \frac{p_\sigma}{g} \int_{\sigma_u}^{\sigma_l} \frac{\partial(\dot{\sigma} q)}{\partial\sigma} \partial\sigma + \frac{W}{p_\sigma} \frac{\partial p_\sigma}{\partial t}$$

The major contribution to change in W comes from the first two terms on the right hand side:

1. The integral of the quasi-horizontal advection of specific humidity by the wind in the layers.

2. The integral of moisture divergence resulting from stretching and shrinking of vertical columns in the model.

The third term is the vertical flux which is assumed to be zero in the model -- no inflow at the bottom and no outflow at the top. The last term gives the time-rate-of-change of pressure difference between the σ-surfaces.

PARAMETERIZATION

The initial moisture analysis and each forecast time step in the PEP model provides W, the total precipitable water in the layer

surface to 400 mb, at each NWP grid point. An idealized vertical distribution of specific humidity is assumed:

$$q = \frac{\alpha W}{\Delta p}$$

where α, a function of pressure, is a modeling parameter which is approximated from climatological radiosonde data as in the earlier SLYH model [1]. With this expression and the appropriate value of α, specific humidities in each of the three σ-layers, the boundary layer and the lower two tropospheric layers, may be determined from W, the total precipitable water in the three layers. From the values of q in each layer, the precipitable water in each layer is computed by the equation for precipitable water so that:

$$W = W_B + \left(W_T\right)_1 + \left(W_T\right)_2$$

REFERENCE:

1. Younkin, R. J., J. A. LaRue, and F. Sanders, 1965: "The Objective Prediction of Clouds and Precipitation Using Vertically Integrated Moisture and Adiabatic Vertical Motions," Journal of Applied Meteorology, 4, 3-17.

FORECAST PROCEDURE

The finite difference form of the precipitable water tendency equation is integrated in 10-minute steps along with the PE model. The PE model provides values of mean u- and v-components of the wind in each layer at each grid point and pressure differences between σ-surfaces for the specific humidity advection term and the last term in the forecast equation. Similarly, values of $\dot{\sigma}$ on each σ-surface are provided for the moisture divergence term. The required integrations are carried out with the given values of σ at the σ-surfaces.

Tendencies of W are determined for each 10-minute time step at each NWP grid point and added to the value of W to give a new value for the next time step in each of the three σ-layers. The three W values are summed to give a total value of W for the three layers.

At the completion of each time step, the forecast W for the three layers is compared with $\hat{W}_S$, 80% (70% May through September) of the saturated precipitable water W_S, determined by the prognostic mean potential temperatures from the PE model in the layers involved. Any excess precipitable water is removed and accumulated for precipitation output. The remaining total precipitable water W is parameterized for q and W in each of the three σ-layers. The forecast procedure is repeated with the simultaneous forecast values

of mean u- and v-components and potential temperatures in the three layers and pressure and $\dot{\sigma}$ differences between the bounding σ-surface from the PE model.

At each output time of 12-, 18-, 24-, 36-, and 48-hours, the forecast total precipitable water for the three layers is converted to relative humidity $\left(\text{R.H.} = \frac{W}{\hat{W}_s}\right)$ at each grid point. As in the initialization procedure for the PEP model, the grid point values of relative humidity are with reference to the reduced saturated precipitation total $\hat{W}_s$ for 80% (or 70%) saturation relative humidity. The relative humidities have the full normal range of 0 - 100%.

The excesses of precipitable water W over $\hat{W}_s$ at each time step are accumulated as quantitative precipitation forecasts for 12-hour periods with output at 12-, 24-, 36-, and 48-hours.

FEED-BACK OF LATENT HEAT

The latent heat due to condensation is fed back into the PE model forecast computation at each time step. The feed-back is confined to the two tropospheric layers where most of the precipitation is assumed to have been generated.

The procedure converts the precipitation at each 10-minute time step to grams/cm^2 which is equated to calories/cm^3. From the assumption of gradient of specific humidity in the vertical, it has been determined that 70% of the latent heat will affect the first tropospheric layer and 30% the second. The total number of calories/cm^3 is divided between the two layers in this way and converted into degrees of heating to be added to the prognostic mean potential temperatures in each layer at each grid point.

The program checks to insure that resultant lapse rates do not exceed the moist adiabatic up to the midpoint of the second tropospheric layer at grid points where precipitation is indicated. Above this level to the tropopause the lapse rate is restricted to not exceeding the dry adiabatic. At grid points where the lapse rate is already moist adiabatic and precipitation is occurring, the program readjusts the division of latent heat equally between the two tropospheric layers to maintain this lapse rate. For other grid points, the readjustment of distribution between the two layers must be between the extremes of 50/50 and 30/70, depending on the departure of forecast lapse rate from moist adiabatic before precipitation begins.

Depiction

A special computer program determines x- and y-coordinates of location points, spaced 1/8" apart on the map scale, along isopleths of standard values of relative humidity. The Curve Follower traces out the location points to draw the relative humidity isopleths for 10, 30, 50, 70, and 90% as solid lines which are hand-labeled. The Curve Follower also indicates the centers of maximum and minimum mean relative humidity by a + with central values printed out in percent. Occasionally, values greater than 100% or less than 0% will be printed out. These are values interpolated by the Curve Follower from the grid point values which are limited to extremes of 10% and 95%.

UP-4; PACKAGE OF NWP UPPER AIR PROGNOSIS

Produced from the operational forecast runs which begin 3+25 hours after 0000Z and 1200Z observation times. These prognoses are on 1:30 million scale.

Description

The output is grouped for facsimile transmission as follows:

a. 24- and 48-hour 500 mb contours, 24-hour with isotachs, for North American area (extended U. S., appendix 14).

b. 12-hour and 36-hour 500 mb contours with isotachs on separate charts, for portion of the Northern Hemisphere (extended front half, appendix 14).

c. 72-hour 500 mb contours for portion of the Northern Hemisphere (extended front half, appendix 14).

d. 24-hour 850 mb with 850-500 mb thickness contours and 700 mb contours with isotachs for North American area (extended U. S., appendix 14).

e. 36-hour 700 mb and 300 mb contours with isotachs for portion of Northern Hemisphere (front half, appendix 14).

f. 24-hour 300 mb and 200 mb contours, with isotherms and isotachs for North American area (extended U. S., appendix 14).

Numerical Models

All of these prognoses through 48 hours are derived from the 6-layer model[1] baroclinic forecast described under chart UP-2. The 72-hour 500 mb prognosis is derived from a barotropic forecast which begins with the 48 hour prognosis as initial data. This is the simpler version of the barotropic model (not the Mesh Model 1964) which uses a percentage of 500 mb winds to compute terrain and friction effects (see references under chart UP-3). The ADP and computer analysis procedures used to obtain initial data for this run are described under chart UA-2.

REFERENCES:

1. Shuman, F. G., et al., "A Multi-Level Primitive Equation Model Suitable for Operational Numerical Weather Prediction", collection of 3 papers, available at NMC, Suitland, Maryland, November 1965.

[1] 3-level baroclinic is used as backup

2. Roberts, C. F., "Present and Future Operational Numerical Prediction Models", ESSA Technical Note 16, Fcsts-3, October 1965.

3. Snellman, L. W., "Sigma surfaces - a replacement for constant pressure surfaces", Western Region Technical Attachment, May 24, 1966.

4. Snellman, L. W., "The Physics of the NMC Primitive Equation Model", Western Region Technical Attachment, June 7, 1966.

5. Badner, J., "Performance of the 6-layer Baroclinic (Primitive Equation) Model", ESSA Technical Memorandum WBTM-FCST-5, Notes to Forecasters No. 5, September 1966.

Derivation of Output

1. 6-Layer Model

The PE model generates grid point (appendix 11) values of pressure and height on the σ-surfaces and of mean u- and v-components of the wind and mean potential temperatures in the σ-layers (appendix 39) for the valid forecast times. The mean values are presumed to apply at the midpoints of the σ-layers.

Potential temperatures and u- and v-components of the wind are interpolated to the constant pressure surfaces from the grid point values in the σ-layers above and below the level in question assuming a linear variation with a function of pressure, π[1].

Heights on the constant pressure surfaces are computed by means of the hydrostatic equation from interpolated potential temperatures and grid point heights and pressures on the closest σ-surface above or below the level in question.

2. 3-Level Baroclinic Model

The 3-level baroclinic model, used as back-up, forecasts stream functions at grid points on the 800 mb, 500 mb and 200 mb surfaces. The stream function field is converted to grid point heights on these surfaces by inversion of the balance equation[2].

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[1] π is the ratio of absolute temperature to potential temperature,

$$\pi = \frac{T}{\theta} = \left(\frac{p}{1000}\right)^{\frac{R}{c_p}} = \left(\frac{p}{1000}\right)^{\frac{2}{7}}$$

[2] The balance equation usually is used to determine the stream function field, from which balanced (non-divergent) winds may be computed, when the height field is known.

700 mb and 300 mb heights are interpolated using an equation of the type

$$H = A + B \cdot H_{850} + C \cdot H_{500} + D \cdot H_{200}$$

The constants, applying at all latitudes, have been determined for each season from a year of radiosonde data.

Temperatures at grid points on the constant pressure surfaces are derived from the forecast heights using regression equations of the same type as those used for interpolating 700 mb and 300 mb heights.

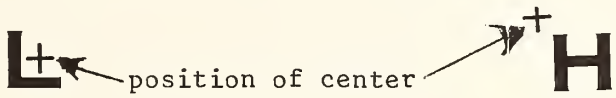
Wind velocities at grid points are computed from the forecast height fields on the constant pressure surfaces using the geostrophic wind equation.

Depiction

A special computer program locates points 1/8" apart on the map scale along the standard isopleths of height, temperature, thickness, and wind velocity by quadratic interpolation from the grid point values. The Curve Follower then traces out these location points to draw the the various isopleths on preprinted facsimile base maps.

1. Contours

Height contours are drawn as solid lines at 60 meter intervals, except 120 meter intervals at 300 mb and 200 mb, hand-labeled in decameters (thousands digit omitted at 200 mb). Intermediate contours are drawn as long-dashed lines at 60 meter intervals on 300 mb and 200 mb charts in areas of weak gradient. Positions of lows and highs are also interpolated and indicated by the Curve Follower. The "L" and "H" symbols always have the relation shown here to the location of the prognostic center.



Centers are labeled in decameters (thousands digit omitted at 200 mb) on 24-hour 300 mb and 200 mb prognostic charts only.

2. Isotherms

Isotherms are drawn by the Curve Follower on a hemispheric base chart. They are then "wheeled"[1] on the facsimile charts at 5°C

[1] The line is produced by a small hand device containing an appropriately notched wheel 3/4" in diameter.

intervals as dotted lines, labeled by hand stamps with appropriate temperature circled on 24-hour 300 mb and 200 mb prognostic charts.

3. Isotachs

Isotachs are drawn as dashed lines at 20 knot intervals, hand-labeled by appropriate velocity with K appended.

4. Thickness

The 850-500 mb thickness field is derived by simple subtraction of 850 mb from 500 mb grid point heights. The Curve Follower draws the 850-500 mb thickness contours as dashed lines at 60 meter intervals, hand-labeled in decameters (only on 24-hour 850 mb prognostic chart).

UP-5; PACKAGE OF 24 & 30 HOUR NWP UPPER AIR PROGNOSIS

This package has been designed as guidance for the High Altitude Meteorological Service. Prognoses transmitted four times per day on a 1:30 million scale include two 24-hour sets valid at 0000Z and 1200Z and two 30-hour sets valid at 0600Z and 1800Z as follows:

a. 24-hour 700 mb and 200 mb prognoses of height contours, isotherms, and isotachs for portion of Front Half of Northern Hemisphere (XX-2 cut, appendix 25a).

b. 24-hour 500 mb and 300 mb prognoses of height contours, isotherms, and isotachs for western North America and a portion of the Pacific (PA-4 cut, appendix 25a).

c. 30-hour 700 mb, 500 mb, 300 mb and 200 mb prognoses of height contours, isotherms, and isotachs for portion of Front Half of Northern Hemisphere (XX-2 cut, appendix 25a).

Numerical Model

All prognoses are produced by the 6-layer (PE) numerical prediction model described under chart UP-2. 24- and 30-hour forecasts come from the same numerical run as charts UP-2 and UP-4 and are based on automatic data processing and computer analyses which begin 3+25 hours after 0000Z or 1200Z.

Derivation of Output

1. 6-Layer Model

The PE model generates grid point (appendix 11) values of pressure and height on the σ-surfaces and of mean u- and v-components of the wind and mean potential temperatures in the σ-layers (appendix 39) for the valid forecast times. The mean values are presumed to apply at the middle of the σ-layers.

Potential temperatures and u- and v-components of the wind are interpolated to the constant pressure surfaces from the grid point values in the σ-layers above and below assuming linear variation with a function of pressure π[1].

[1] π is the ratio of absolute temperature to potential temperature,

$$\pi = \frac{T}{\theta} = \left(\frac{p}{1000}\right)^{\frac{R}{c_p}} = \left(\frac{p}{1000}\right)^{\frac{2}{7}}$$

Heights on the constant pressure surfaces are computed by means of the hydrostatic equation from interpolated potential temperatures and heights and pressures on the closest σ-surface above or below the level in question.

2. 3-Level Model

The 3-level baroclinic model used as back-up forecasts stream functions at grid points on the 800 mb, 500 mb, and 200 mb surfaces. The stream function field is converted to grid point heights on these surfaces by inversion of the balance equation[1].

700 mb and 300 mb heights are interpolated using an equation of the type

$$H = A + B \cdot H_{850} + C \cdot H_{500} + D \cdot H_{200}$$

The constants applying at all latitudes have been determined for each season from a year of radiosonde data.

Temperatures at grid points on the constant pressure surfaces are derived from the forecast heights using regression equations of the same type as those used for interpolating 700 mb and 300 mb heights.

Wind velocities at grid points are computed from the forecast height field on the constant pressure surfaces using the geostrophic wind equation.

Depiction

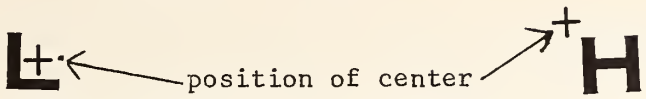
A special computer program locates points 1/8" apart on the map scale along standard isopleths of height, temperature and wind velocity on e each of the constant pressure surfaces by quadratic interpolation from the grid point values. The Curve Follower then traces out these location points to draw the various isopleths on preprinted facsimile base maps (except isotherms).

1. Contours

Height contours are drawn as solid lines at 60 meter intervals on 700 mb and 500 mb charts. On 300 mb and 200 mb charts, contours are drawn as solid lines at 120 meter intervals, with intermediate contours as long-dashed lines at 60 meter intervals in areas of weak gradient. Contours are hand-labeled in geopotential decameters. (thousands digit is omitted at 200 mb). Low and high centers are

[1]The balance equation usually is used to determine the stream function field, from which balanced (non-divergent) winds may be computed, when the height field is known.

indicated by "L" and "H" symbols which have the relation shown here to the prognostic center.



2. Isotherms

Isotherms are drawn by the Curve Follower on a hemispheric base chart and are then "wheeled"[1] on the facsimile charts at 5°C intervals as dotted lines labeled by hand stamps with appropriate temperatures circled.

3. Isotachs

Isotachs are drawn as dashed lines at 20 knot intervals, hand-labeled by appropriate velocity with K appended.

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[1]The line is produced by a small hand device containing an appropriately notched wheel 3/4" in diameter.

UP-6; 36-HOUR 500 MB 6-LAYER HEIGHT ERROR

Issued twice daily from 0000Z and 1200Z upper air observations for the front half of the Northern Hemisphere on a 1:30 million scale chart (appendix 14).

Numerical Models

36-hour 500 mb prognostic heights are produced by the 6-layer (PE) numerical prediction model[1] described under charts UP-2 and UP-4 for the hemispheric network of NWP grid points (appendix 11). The verifying 500 mb heights come from the computer automatic data processing and analysis procedures which begin 3+25 hours after observation time. 95% of the data has been received by this time through operational and special communication channels. Procedures are similar to those described under chart UA-2.

Derivation and Depiction

Analyzed 500 mb heights are subtracted from 36-hour prognostic 500 mb heights to give an algebraic forecast height difference for each grid point. A special computer program determines the location of a set of points 1/8" apart on the map scale along standard isopleths of height error by quadratic interpolation from the grid point values.

The Curve Follower then traces out these location points to draw the isopleths as solid lines on a preprinted facsimile base map. The zero line and lines of positive and negative 60 meter increments are drawn. Isopleths of error are hand-labeled in decameters.

Positions of maximum height error are printed by the Curve Follower as + or - as appropriate, labeled in decameters.

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[1] 3-level baroclinic model used as back-up.

UP-7; NWP LIFTED INDEX PROGNOSES

Prepared twice a day from 0000Z and 1200Z upper air data covering the North American area on a 1:30 million scale. Chart consists of four panels including an initial analysis and 12-, 24- and 36-hour prognoses of the Lifted Index.

Description

1. Definition

The lifted index is defined as the 500 mb temperature minus the temperature of a parcel lifted from near the surface of the earth to 500 mb. Negative values indicate instability.

2. Numerical Model

The lifted index initial analysis and prognoses are produced by the 6-layer (PE) numerical prediction model described under charts UP-2 and UP-4. In the model, the analyzed or forecast mean pressure, temperature and dewpoint in the boundary layer (appendix 39) are taken to be those describing a parcel which then is raised to 500 mb. The resulting parcel temperature is compared with the analyzed or forecast 500 mb temperature. The difference gives the analyzed or forecast lifted index.

The parameters are derived from the model as follows:

a. Pressure

The boundary layer in the model is fixed at 50 mb above the surface of the earth. The pressure at the surface of a highly smoothed topography representing the real terrain is computed in the initial analysis procedure and forecast for each 10-minute time step (described under chart UP-2). The mean pressure representing the pressure of the layer is given in millibars by:

$$\bar{p} = p^* - 25$$

(where p^* is the pressure at the surface).

b. Dewpoint

The Primitive Equation Precipitation (PEP) model (described under chart UP-3) forecasts the total precipitable water W in a layer which includes the lowest three σ-layers of the PE model (appendix 39), from the surface to near 400 mb. An assumption about the vertical distribution of moisture must be made in order to determine the portion of the total precipitable water to be allotted

to the boundary layer. A modeling parameter α, obtained from climatological moisture soundings, is used. An appropriate value for α averaged over the boundary layer is taken as 3.5 (dimensionless).

The specific humidity (mass of water vapor per unit mass of moist air mixture) for the boundary layer is given by

$$q = 3.5 \frac{gW}{p^*}$$

where g is gravity, W is total precipitable water and p* is pressure at the surface.

The mean vapor pressure $\bar{e}$ is obtained from

$$q = 0.622 \frac{\bar{e}}{\bar{p} - 0.378\bar{e}}$$

and substituted into the empirical formula

$$e_s = 6.11 \times 10^C$$

where

$$C = \frac{7.5t}{t + 237.3}$$

Solution for t gives the temperature at which the observed vapor pressure would be the saturation vapor pressure. This temperature is mean dewpoint of the boundary layer.

c. Temperature

The mean potential temperatures in each σ-layer of the PE model are analyzed and forecast routinely from the thermodynamic energy equation (see chart UP-2). The effects of solar heating, radiative cooling and heating over oceans is included for the boundary layer. (Latent heat of condensation affects only the two layers above the boundary layer). The mean potential temperature in the boundary layer is converted to Celsius temperature by

$$\bar{t} = \left(\frac{\bar{p}}{1000}\right)^{2/7} \bar{\theta} - 273.16$$

3. Derivation

The parcel defined by the boundary layer conditions is lifted, in effect, dry adiabatically to the lifting condensation level (LCL--the point at which the mixing ratio of the parcel becomes equal to the saturation mixing ratio given by the original pressure and dew-

point of the parcel). The parcel then is lifted moist adiabatically (along the pseduo-adiabat through the LCL point) to 500 mb to find the temperature at that level. The parcel 500 mb temperature is subtracted from the observed or forecast 500 mb temperature (determined as described under charts UA-2 and UP-5). This operation is performed at each grid point (appendix 11) for each 10-minute time step and the lifted index read out at 12-hour intervals.

4. References

a. Stackpole, J. D., 1967: Detailed Sounding Analysis and Computer Forecasts of the Lifted Index. ESSA Technical Memorandum WBTM-NMC 41.

b. _____, 1967: Numerical Analysis of Atmospheric Soundings, J. Appl. Meteor., 6, 464-467.

c. Younkin, R. J., J. A. LaRue and F. Sanders, 1965: The Objective Prediction of Clouds and Precipitation Using Vertically Integrated Moisture and Adiabatic Vertical Motions, J. Appl. Meteor., 4, 3-17.

5. 850-500 mb Thickness

850-500 mb thickness values at each grid point are determined by subtraction of 850 mb from 500 mb heights at initial and 12-, 24-, and 36-hour prognostic times. The PE model procedures for extracting these heights is described under charts UA-2, UA-3a, UP-2, and UP-4.

Depiction

A special computer program determines the locations of points 1/8" apart on the map scale along standard isopleths of Lifted Index and 850-500 mb thickness by quadratic interpolation from the grid point data. The Curve Follower traces out the location points as:

1. Solid lines at intervals of $\pm$ 4° C for Lifted Index, hand-labeled.

2. Dashed lines at 60 meter intervals for 850-500 mb thickness, hand-labeled in decameters.

Centers of maximum positive and negative Lifted Index with labeled values are printed out by the Curve Follower. Centers of high and low thickness values are printed out also with centers indicated by + labeled in decameters.

UP-8; 24-HOUR ABSOLUTE VORTICITY PROGNOSIS

Produced twice daily from 0000Z and 1200Z upper air data on a 1:30 million scale for the Front Half of the Northern Hemisphere (appendix 14).

Numerical Models

Absolute vorticity forecasts are derived from the output of the 6-layer (PE) numerical prediction model (3-level baroclinic model back-up) described under charts UP-2 and UP-4.

Derivation

The PE model furnishes 24-hour forecasts of mean u- and v-components of the wind in each of the six layers (appendix 39) at each NWP grid point (appendix 11). The wind components are presumed to apply at the mid-points of the layers.

1. The u- and v-components at 500 mb are interpolated from the values in the layers above and below 500 mb assuming a linear variation with a function of pressure π[1].

2. The absolute vorticity at each grid point is computed from the wind component fields by means of the equation

$$\eta = \zeta + f = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} + f$$

where ζ is the relative vorticity and f is the Coriolis parameter.

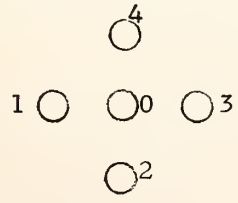
The 3-level baroclinic model, used as backup, provides 24-hour forecasts of stream function at each grid point on the 500 mb surface. The relative vorticity at each grid point is computed from the Laplacian[2] (∇^2) of the stream function field and the Coriolis parameter added to give absolute vorticity.

[1] π is the ratio of absolute temperature to potential temperature.

$$\pi = \frac{T}{\theta} = \left(\frac{p}{1000}\right)^{\frac{R}{c_p}} = \left(\frac{p}{1000}\right)^{\frac{2}{7}}$$

[2] $\nabla^2 \Psi = \frac{\partial^2 \Psi}{\partial x^2} + \frac{\partial^2 \Psi}{\partial y^2} = \zeta$ where Ψ is the stream function and ζ the relative vorticity

In finite difference this means:



taking the sum of the values at grid points 1, 2, 3, and 4 and subtracting 4 times the value at 0. $\frac{(1+2+3+4-4(0))}{\Delta \text{ grid interval}}$

Vorticities from both models are not computed directly from the height field and are smoothed separately from heights. Therefore vorticity computations from the height contours may not duplicate the transmitted values.

Depiction

A special computer program determines the location of points 1/8" apart on the map scale along standard isopleths by quadratic interpolation from grid point values of absolute vorticity. The Curve Follower traces out the location points as solid lines at intervals of 2×10^{-5} sec^{-1} on the preprinted facsimile chart. Absolute vorticity isopleths are hand-labeled by 2, 4, 6, etc., multiples of 10^{-5} sec^{-1}. Centers of maximum and minimum absolute vorticity indicated by + labeled in multiples of 10^{-6} sec^{-1} are interpolated and printed by the Curve Follower on the charts.

UP-8A; COMPOSITE VORTICITY/VERTICAL VELOCITY PROGNOSIS

Produced twice daily from 0000Z and 1200Z upper air data for the northern portion of the North Pacific (cut PN-3, appendix 25a) on a 1:30 million scale. Transmitted chart consists of three panels containing:

1. Initial 500 mb vorticity isopleths.
2. 24-hour prognostic 500 mb vorticity isopleths.
3. 24-hour prognostic 700 mb vertical velocity isopleths.

This chart is intended as guidance for the High Altitude Meteorological Service.

Derivation and Depiction

The automatic data processing and analysis procedures for deriving the initial 500 mb vorticity field and the depiction of vorticity isopleths are described under chart UA-2.

The methods by which the 24-hour prognostic vorticity and vertical velocity fields are derived from the 6-layer (PE) numerical prediction model and the depiction of isopleths are described under charts UP-2 and UP-8.

All three panels represent special cuts of the PE model output which covers the Northern Hemisphere.

UP-9; PACKAGE OF 18 & 24 HOUR NWP UPPER AIR PROGNOSIS

This package has been designed as a set of operational charts for the High Altitude Meteorological Service. Prognoses are transmitted four times per day on a 1:20 million scale covering the northern portion of the North Pacific, North America, the North Atlantic and Europe (XX-1 cut, appendix 25). The package includes 700 mb, 500 mb, and 300 mb prognoses: two 18-hour sets, valid at 0600Z and 1800Z; and two 24-hour sets, valid at 0000Z and 1200Z. Charts contain height contours, isotachs and spot temperatures.

Numerical Models

All prognoses are produced by the 6-layer (PE) numerical prediction model[1] described under chart UP-2. 18- and 24-hour forecasts come from the same numerical run as charts UP-2, UP-4, and UP-5, and are based on automatic data processing and computer analyses which begin 3+25 hours after 0000Z or 1200Z.

Derivation of Output

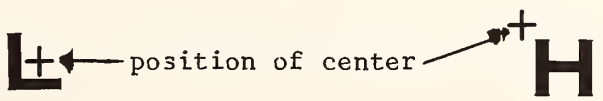
Heights, temperatures and winds on constant pressure surfaces at the NWP grid points (appendix 11) are derived from the PE model or back-up 3-level baroclinic model as described under charts UP-4 and UP-5.

Depiction

A special computer program locates points 1/8" apart on the map scale along standard isopleths of height, temperature and wind velocity on each of the constant pressure surfaces by quadratic interpolation from the grid point values. The Curve Follower then traces out these location points to draw the various isopleths on preprinted facsimile base maps (except isotherms).

1. Contours

Height contours are drawn as solid lines at 60 meter intervals on 700 mb and 500 mb charts. On 300 mb charts, contours are drawn as solid lines at 120 meter intervals, with intermediate contours as long-dashed lines at 60 meter intervals in areas of weak gradient. Contours are hand-labeled in geopotential decameters. Low and high centers are indicated by "L" and "H" symbols which have the relation shown here to the prognostic center.



[1] 3-level baroclinic model is used as back-up.

2. Temperatures

Isotherms are drawn by the curve follower on a hemispheric base chart. Spot temperatures at significant locations from these isotherms are indicated on the facsimile charts by hand-stamped circled temperatures at 5°C intervals.

3. Isotachs

Isotachs are drawn as dashed lines at 20 knot intervals, hand-stamped by appropriate velocity with K appended.

4. Jet Cores

Jet cores at 300 mb are subjectively determined by an analyst and drawn by hand as heavy arrows. The isotach patterns are used as the primary guide. These are interpreted in terms of current or past jet core positions, vertical consistency and contour crossing normally expected with accelerating or decelerating winds.

UP-10; TROPOPAUSE MAXIMUM WIND/WIND-SHEAR PROGNOSES

Produced by computer for the United States (48-state portion) on a 1:25 million scale. Transmitted four times per day. The prognoses valid at 0600Z and 1200Z are 18- and 24-hour forecasts respectively from 1200Z initial time; those valid at 1800Z and 0000Z are 18- and 24-hour forecasts respectively from 0000Z.

Numerical Model

These prognoses are derived from the output of the 6-layer (PE) numerical prediction model described under charts UP-2 and UP-4. The model produces forecasts of mean u- and v-components of the wind in each σ-layer and computes pressures and heights of the tropopause and the other σ-surfaces (appendix 39) at each NWP grid point (appendix 11) for each 10-minute time step. The mean layer winds are assumed to apply at the midpoints of the layers, determined by averaging the heights of the bounding σ-surfaces.

Derivation

The numerical wind-shear model is based on a set of assumptions about the structure of the upper troposphere and lower stratosphere. These assumptions are used also in the tropopause and wind-shear analysis (Chart UA-6) and were used in the manual program.

1. There is one maximum wind level.

2. The tropopause surface and level of maximum wind are coincident.

3. Wind directions vary little with height through the region of concern (20,000 to 50,000 feet).

4. Averaged positive wind shears below the tropopause-maximum wind level are approximately equal to averaged negative shears above.

5. Time and space variations of the level of maximum wind and smoothed shears above and below are not erratic.

The computer program makes the following computations at each grid point for 18-, 24-, 30-, 36-, 42-, and 48-hours after observation time:

1. The PE model provides pressures and heights of the tropopause and other σ-surfaces.

2. The maximum wind velocity at the tropopause is computed from the formula:

$$V_{max} = 1/2 \left(\overline{V}_2 + \overline{V}_3\right) + 1/4 \left(\overline{V}_2 - \overline{V}_1\right) + 1/4 \left(\overline{V}_3 - \overline{V}_4\right)$$

where $\overline{V}$ is the mean scalar wind $\left(\sqrt{u^2 + v^2}\right)$ in the layer indicated by the subscript (appendix 39).

3. The average scalar wind-shear is computed using the formula:

$$\text{wind-shear} = 1/2 \quad \frac{V_{max} - \overline{V}_1}{Z_{max} - \overline{Z}} + \frac{V_{max} - \overline{V}_4}{Z_{max} - \overline{Z}_4}$$

where Z_{max} is the height of the tropopause surface and $\overline{Z}$ is the mean height in the layer indicated by the subscript (appendix 39). The averaging covers the region from about 10,000 feet above to 13,000 feet below the tropopause.

4. The computer program forms stream functions from the u- and v-components of the maximum wind at the tropopause.

A special computer program determines the x- and y-coordinates of points, spaced 1/8" apart on the map scale, along standard isopleths of the various parameters by quadratic interpolation from grid point values. The Curve Follower traces out the location points to draw:

1. Isopleths of stream function parallel to the direction of the maximum wind at the tropopause with spacing governed by the wind speed (equivalent to 120 meter contour spacing).

2. Isotachs of maximum wind speed at 20 knot intervals.

3. Isopleths of intersections of the tropopause with the standard constant pressure surfaces: 150, 200, 250, 300, 400, and 500 mb.

4. Isopleths of average vertical wind-shear at 2-knot intervals.

All sets of lines are drawn at the 1:20 million scale. The resulting analyses are photo-reduced to 1:25 million scale for hand-tracing on the facsimile base charts.

Depiction

The prognosis are depicted on two panels comprising half of a standard facsimile chart (transmitted with the High-Level Significant Weather Prognosis, chart UP-11).

The upper panel contains:

1. Prognostic flow lines at the maximum wind-tropopause level hand-traced from the stream function analysis as very long-dashed lines with arrowheads at irregular intervals but sufficient to depict the general flow.

2. Prognostic isotachs hand-traced as dotted lines at 20-knot intervals labeled in knots.

3. The axis of the jet core depicted as a long-dashed heavy line with arrowheads, hand-drawn through the isotach maxima with regard for vertical consistency.

The lower panel contains:

1. Isopleths of intersection of the tropopause with the standard constant pressure surfaces traced as solid lines. These are hand-labeled to nearest 1000 feet with reference heights of a standard atmosphere at each constant pressure surface:

   150 mb -- 45,000 feet; 200 mb -- 39,000 feet;
   250 mb -- 34,000 feet; 300 mb -- 30,000 feet;
   400 mb -- 24,000 feet; and 500 mb -- 18,000 feet.

   The labeled heights will be too high where the D-values for the intersections are negative and too low where they are positive.

2. Isopleths of average vertical wind-shear traced as short-dashed lines hand-labeled in knots per 1000 feet for each 2 knots of shear.

3. The axis of the jet core as in the upper panel.

UP-10A; TROPOPAUSE/VERTICAL WIND-SHEAR PROGNOSES

Produced by computer for the northern portion of the North Pacific, North America, the North Atlantic and Europe (cut XX-1, appendix 25) on a 1:20 million scale. Transmitted four times per day. The prognoses valid at 0600Z and 1200Z are 18- and 24-hour forecasts respectively from 1200Z initial time; those valid at 1800Z and 0000Z are 18- and 24-hour forecasts respectively from 0000Z. Prognoses are a part of the set of operational charts for the High Altitude Meteorological Service described under chart UP-9.

Numerical Models

This chart is an expanded version of the tropopause/wind shear panel of chart UP-10. "Spot" temperatures at the tropopause and at 150 mb are additional features.

The numerical model is discussed under chart UP-10. In addition to mean u- and v-components of the wind in the σ-layers and pressures and heights of the σ-surfaces (appendix 39), the PE model provides forecasts of mean potential temperature in each σ-layer at each grid point (appendix 11) for each 10-minute time step.

Derivation

The computer program makes the following computations at each grid point for 18-, 24-, 30-, 36-, 42-, and 48-hours after observation time:

1. The PE model provides pressures and heights of the tropopause and other σ-surfaces.

2. The numerical wind-shear model described under chart UP-10 produces averaged vertical wind-shears for the region from about 10,000 feet above to 13,000 feet below the tropopause.

3. A linear variation of potential temperature with a function of pressure π[1] is assumed. Mean potential temperatures in the two stratospheric σ-layers are extrapolated downward to the tropopause pressure. Similarly, mean potential temperatures in the top two tropospheric σ-layers are extrapolated upward to the tropopause pressure. The tropopause temperature is taken as the average of the two extrapolated temperatures[2].

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[1] π is the ratio of absolute temperature to potential temperatures:

$$\pi = \frac{T}{\theta} = \left(\frac{p}{1000}\right)^{\frac{R}{c_p}} = \left(\frac{p}{1000}\right)^{2/7}$$

[2] Potential temperature is converted to temperature in degrees Celsius by:

$$t = \left(\frac{p}{1000}\right)^{2/7} \theta - 273.2$$

4. The temperatures at 150 mb is interpolated from the mean potential temperatures in the σ-layers above and below this level.

A special computer program determines the x- and y-coordinates of points, spaced 1/8" apart on the map scale, along standard isopleths of the various parameters by quadratic interpolation from the grid point values.

Depiction

The Curve Follower traces out the location points to draw directly on the preprinted facsimile base charts:

1. Isopleths of intersections of the tropopause with isobaric surfaces from 350 mb through 150 mb at 50 mb intervals. These are drawn as solid lines and are hand-stamped with pressures in millibars.

2. Isopleths of average vertical wind shear drawn as short-dashed lines at intervals of 2 knots, hand-stamped in knots.

The Curve Follower draws isotherms at 5°C intervals at the tropopause and at 150 mb on Northern Hemisphere base charts. From these "spot" temperatures in degrees Celsius sufficient to delineate the thermal pattern are hand-stamped on the facsimile chart. Tropopause temperatures are circled; 150 mb temperatures are enclosed in a square.

UP-11; HIGH LEVEL SIGNIFICANT WEATHER PROGNOSES

Forecasts of significant cloudiness, thunderstorms, turbulence and icing from 400 mb through 150 mb; valid four times daily at 0000Z, 0600Z, 1200Z, and 1800Z; on a 1:20 million scale covering the 48 states of the United States, adjacent Canada, Mexico, and off-shore areas.

Preparation

This prognosis is prepared 10-11 hours before valid time. The charts are transmitted on the High Altitude Facsimile Circuit about 9 hours before valid time and again on the National Weather Facsimile Network about 7 1/2 hours before valid time. Prognostic surface fronts and pressure centers are included in the High Altitude transmission. The National Facsimile transmission is the high-level portion of the FN Depiction Package (charts SP-4 and UP-10).

This prognosis is based on the 18- and 24-hour operational High Altitude prognoses (charts UP-9 and UP-10). It is also closely coordinated with the low-level significant weather prognoses (chart SP-4).

Derivation and Depiction

1. Prognostic surface fronts and centers, depicted as shown in appendix 2, are interpolated between the 12-hour and 24-hour positions of the low-level significant weather prognosis (chart SP-4). They are adjusted for the indications of the latest surface analysis.

2. Prognostic areas of thunderstorm activity are depicted as enclosed by a solid line. Tops of cumulonimbus are indicated in hundreds of feet. The areas are based on the last low-level significant weather prognosis (chart SP-4) and coordinated with the latest available watch from the National Severe Storms Forecast Center in Kansas City. Thunderstorm tops generally are forecast no more than 2,000 feet above the tropopause level. Unless otherwise indicated, prognostic thunderstorms and cumulonimbus clouds imply moderate turbulence and icing.

3. Prognostic areas of 6/8 or more coverage of cirriform clouds are outlined by a scalloped line. These are based on models derived by P. W. Kadlec [1] which associate cirriform clouds with large-scale flow patterns and with the jet-core. PIREPS and surface observations are available to check the extent and altitude of cirriform cloud areas currently in existence. Tops and bases are indicated in hundreds of feet.

4. Prognostic areas of more than 50% probability of moderate or greater Clear Air Turbulence are inclosed by a dashed line with appropriate symbol and base and top indicated in hundreds of feet. These areas are forecast with conditions of strong vertical vector shear. These conditions occur most often:

(a) On the left side of strong jets (i.e., one isotach $\geq$ 125 knots at 300 mb) looking downstream between the trough and upstream ridge where the averaged vertical scalar shear (as given on chart UP-10) is greater than 6 knots/1000 feet. This area is most likely to have moderate or greater CAT when, on the latest 300 mb chart, an area of cold air advection is also indicated as impinging on the left side of the jet stream.

(b) In the "entrance zone" between two confluent jet cores in the region where the cores are 3 to 5 degrees, or less, of latitude apart.

(c) In sharp, V-shaped troughs which slope rapidly with elevation below 300 mb.

(d) In the "neck" of cut-off lows.

(e) To the right (looking downstream) of strong anti-cyclonically curved jet streams.

(f) Over mountain ranges, when the jet core crosses at right angles to the major axis of the range, and winds at the top of the mountain are at least 25 knots.

The vertical extent of CAT area is generally forecast no higher than 2000 feet above the tropopause and within the layers in which the conditions listed above are occurring. Often, however, tools are not available to define the vertical extent of CAT 15 to 18 hours in advance.

Recent references containing material used in NMC's CAT forecasts are:

REFERENCES:

1. Kadlec, P. W., "A Study of Flight Conditions Associated with Jet Stream Cirrus, Atmospheric Temperature Change, and Wind Shear Turbulence", Final Report USWB Contract CWB-10888, June 1965.

2. Reiter, E., and Nania, A., "Jet Stream Structure and CAT", Journal of Applied Meteorology, Volume 3, No. 3, June 1964.

3. Sorenson, J. E., "Synoptic Patterns for CAT", United Air Lines Meteorology Circular, No. 56, December 21, 1964.

4. George, J. J., "Airline Practices in Forecasting Clear Air Turbulence", Proc. ION-SAE Conf., CAT Meeting, Washington, D. C., February 23-24, 1966.

5. Hanson, D. M., et al., "Procedures for Forecasting Clear Air Turbulence", OFDEV Technical Note No. 5, USWB, January 1962.

6. Colson, De Ver, "Analysis of Clear Air Turbulence Data for March, 1962", Monthly Weather Review, Volume 91, No. 2, February 1963, pp 73-82.

7. Harrison, H. T., and Sowa, D. F., "Mountain Wave Exposure on Jet Routes of NWAL and UAL", United Air Lines, Meteorology Circular No. 60, February 1, 1966.

UP-12; ANC HIGH ALTITUDE FORECASTS

Significant weather prognosis 700-150 mb from Anchorage High Altitude Forecast Office covering routes from the Pacific Northwest and Alaska to Japan (PN-1 cut, appendix 25) on a 1:20 million scale. Transmitted four times daily, valid at 0000Z, 0600Z, 1200Z, and 1800Z. The corresponding 700 mb, 500 mb, 300 mb, and tropopause/vertical wind-shear prognoses of the High Altitude package are computer produced at the National Meteorological Center and are described under chart UP-9.

Amendments

AIREPS within ±3 hours of valid time are plotted on the appropriate 300 mb prog prepared by NMC. Areas with serious wind and/or temperature errors (040° and 40 knots for winds and 5° for temperatures) are amended by issuance of a plain language message to facilities at Anchorage, Cold Bay, Kodiak Naval Base, Vancouver, Seattle, San Francisco, and Tokyo. These amendments normally apply corrections to prog charts by zones within specified latitudes, as, for example, REF ANC 300 MB PROG VALID 26/1200Z INCR WNDS BY 60 TO 80 KT ZONES 34, 35, 36, 01 FROM 45 TO 52N. ON 26/1800Z PROG INCR WNDS ZONES 33, 34, 35 BY 40 TO 60 KT FROM 46 TO 51N.

If the error persists for more than two successive progs, the situation is brought to the attention of the Chief Meteorologist at NMC via the High Altitude Intercom.

Significant Weather

1. GUIDANCE

   a. Objective 24- and 30-hour surface prognoses from the 6-layer (PE) numerical prediction model (chart SP-1A) for valid forecast times.

   b. Operational numerical 700 mb, 500 mb, 300 mb and tropopause/vertical wind-shear prognoses (charts UP-9 and UP-10A) for valid forecast times.

   c. 24-hour numerical vorticity and vertical motion prognoses (chart UP-8A) from 0000Z and 1200Z initial data.

2. TOOLS AVAILABLE

   a. Preliminary manual surface analyses for the North Pacific from the National Meteorological Center (chart SA-2) available for 0000Z, 0600Z, 1200Z, and 1800Z.

   b. 500 mb computer analyses for the North Pacific available for 0000Z and 1200Z (chart UA-3).

c. 300 mb computer analyses for the northern portion of the North Pacific available for 0000Z and 1200Z (chart UA-3A).

d. Locally prepared 1:7.5 million surface analyses (Northeastern Pacific).

e. APT cloud mosaics (North Pacific east of 165° east longitude)

f. Nephanalyses

g. AIREPS

h. Norwegian models

3. PREPARATION:

Analyzed surface frontal positions and isobars on the NMC 1:20 million preliminary surface analyses for the North Pacific are modified as necessary to fit late ship reports and delayed Russian data. The NMC guidance surface progs are used as a first approximation for prognostic fronts and isobars, but modified to accommodate latest surface developments. Prog is completed at H + 10 enabling the forecaster to utilized the synoptic surface map 18 hours prior to valid time. Cloud structures are based on the usually accepted models, heavily-weighted toward the latest APT pictures. Areas of suspected turbulence (other than frontal or thunderstorm) are based largely on horizontal and vertical wind shears associated with a jet stream, zones of sharp contour curvature at 500 and 300 mb, vicinity of the jet over rapidly deepening storms, on the right side of the jet stream in zones of anticyclonic curvature, and over mountainous terrain under strong trans-mountain flow conditions. APT cloud photographs showing well-developed transverse waves (normal to jet stream flow) also serve as guidance for turbulent areas. Locations of the 0° isotherm at 5,000 and 10,000 feet (rarely at 15,000 feet) are based on the isotherms on the concurrent 700 mb prog prepared by NMC for the ANC High Altitude Area.

Depiction

1. Prognostic surface fronts are depicted by heavy solid lines; isobars by thin solid lines labeled in millibars. Pressure centers are indicated by high and low symbols labeled in millibars.

2. Locations of 0° C isotherm at 5,000, 10,000, and 15,000 feet are indicated by short-dashed lines appropriately labeled.

3. Cloud areas are enclosed by scalloped lines and labeled with eights of coverage and type.

4. Turbulence areas are enclosed by heavy long-dashed lines and labeled by symbols (⌒ moderate and ⌃ severe). "Spot" symbols are used also.

5. Icing is indicated by appropriate symbols (Ψ moderate and Ψ severe).

6. Thunderstorms are indicated by symbol ⚡ .

7. Vertical extent of significant weather is indicated by bases and tops in hundreds of feet.

UP-13; SFO HIGH ALTITUDE FORECASTS

18-hour prognoses of 700 mb, 500 mb, 300 mb, composite 200 mb/tropopause and composite surface/significant weather (surface to 150 mb) from San Francisco High Altitude Forecast Office on a 1:20 million scale covering routes from Pacific Coast to Hawaii (cut PA-3, appendix 25). Valid about 12 hours after transmission time at 0000Z, 0600Z, 1200Z, and 1800Z.

Forecast Procedures

1. GUIDANCE:

   NMC charts are relied upon for basic guidance, refined with respect to local detail and up-dated as necessary in view of later data received, especially from aircraft in flight.

2. TIME AVAILABLE:

   a. Approximately one and one-half hours average time is required for development of each prognostic chart and for copying in "finished" form for Fax transmissions.

   b. Data cut-off time is H plus 6 hours for basic observations (surface, RAOB, and RAWIN) and H plus 8 hours for reports from aircraft in flight.

3. PREPARATION:

   The sea-level, 700 mb, 500 mb, and 300 mb levels are inter-related hydrostatically; from 300 to 200 mb, a vertical relationship of troughs and ridges is primarily assumed but modified as necessary to accommodate observed slopes and/or differences in amplitude and strength of gradient.

   Clear Air Turbulence is forecast on the basis of vertical wind shears and strong horizontal wind shears such as at sharp troughs or shear lines.

   Tropopause heights and configurations are geared to 500 mb isotherms as revealed at observed points, and thus are in a general sense related to potential temperatures.

   REFERENCES:

   1. Stanford Research Institute publication of June 1964 "Clear-Air Turbulence and Its Analysis", under Weather Bureau Contract CWB-10624.

2. Stanford Research Institute publication of May 1963, "Detailed Structure of the Atmosphere in Regions of Clear-Air Turbulence", contract CWB-10324.

3. Eastern Airlines "Study of Flight Conditions..and Wind Shear Turbulence", June 1964, under Weather Bureau contract CWB-10674.

4. Eastern Airlines "Flight Data Analysis....of Clear-Air Turbulence", June 1965, CWB-10888.

5. United Airlines Meteorological Circular #56, December 1964, "Synoptic Patterns for Clear-Air Turbulence".

D e p i c t i o n

1. Height contours are drawn as solid lines. Intervals are 200 feet at 700 mb and 500 mb with intermediate long-dashed contours at 100 feet in areas of weak gradient. At 300 mb and 200 mb, intervals are 400 feet with intermediate long-dashed contours with arrowheads in direction of flow at 200 feet. Contours are labeled in feet. Height centers are indicated by high and low symbols.

2. Isotachs are drawn as short-dashed lines at 20 knot intervals up to 140 knots and 40 knot intervals above 140 knots labeled in knots by stamps. The 10 knot isotach is indicated also.

   "Spot" winds are indicated by arrows and barbs: at 600 mb on the 700 mb chart, at 400 mb on the 500 mb chart, and at 250 mb on the 300 mb chart.

3. Encircled "spot" temperatures are plotted in sufficient density to delineate the thermal field.

4. Heavy long-dashed lines indicate the intersection of the tropopause with constant pressure surfaces at intervals of 50 mb at and below 150 mb appropriately labeled on the composite 200 mb/tropopause chart. Mean tropopause temperatures are entered in boxes along these lines.

5. Composite surface/significant weather prognosis.

   a. Fronts are depicted in the usual manner (appendix 2). Isobars are depicted by solid lines labeled in millibars. Pressure centers are indicated by high and low symbols.

   b. Locations of the 0° C isotherm at 2,500 foot intervals of height are indicated by short-dashed lines appropriately labeled.

c. Cloud areas are enclosed by scalloped lines and labeled by eighths of coverage and type.

d. Turbulence areas are enclosed by heavy broken lines and labeled by symbols (moderate and severe). "Spot" symbols are used also.

e. Icing is indicated by appropriate symbols (moderate and severe).

f. Thunderstorms are indicated by symbol .

g. Vertical extent of significant weather is indicated by bases and tops in hundreds of feet.

UP-14; JFK HIGH ALTITUDE FORECASTS

Significant weather prognosis 700-150 mb from Kennedy High Altitude Forecast Center covering the northern portion of the North Atlantic (NT-/ cut, appendix 25) on a 1:20 million scale. Transmitted four times daily, valid at 0000Z, 0600Z, 1200Z, and 1800Z. The corresponding 700 mb, 500 mb, 300 mb, and tropopause/vertical wind shear prognoses of the High Altitude package are computer produced at the National Meteorological Center and are described under chart UP-9.

Amendments

JFK is responsible for monitoring and amending the numerically produced operational prognostic package for the North Atlantic transmitted on the High Altitude Facsimile Circuit. Amendments are issued in narrative form via local teletype, telautograph and facsimile in the New York City area and encoded in digital format for possible future relay by NMC over the high speed AIRINC teletype circuit.

Significant Weather

1. GUIDANCE

   a. Objective 24- and 30-hour surface prognoses from the 6-layer (PE) numerical prediction model (chart SP-1A) for valid forecast times.

   b. Operational numerical 700 mb, 500 mb, 300 mb and tropopause/vertical wind shear prognoses (charts UP-9 and UP-10A) for valid forecast times.

2. TOOLS AVAILABLE

   a. Preliminary manual surface analysis for the North Atlantic from the National Meteorological Center (chart SA-2) available for 0000Z, 0600Z, 1200Z, and 1800Z updated at JFK with late and supplementary data.

   b. 500 mb and 300 mb computer analyses for the North Atlantic available for 0000Z and 1200Z (chart UA-3) updated at JFK with late and supplementary data.

   c. Observed and forecast vorticity fields (charts UA-2 and UP-8).

   d. Aircraft reports from the North Atlantic.

   e. Satellite pictures (APT)

Depiction

1. Prognostic fronts are depicted by solid lines pipped in the usual manner. Pressure centers are indicated by high and low symbols labeled in millibars.

2. Location of the 0° C isotherm at 10,000 feet is indicated by a short-dashed line appropriately labeled.

3. Cloud areas are enclosed by scalloped lines and labeled with eights of coverage and type.

4. Turbulence areas are enclosed by heavy long-dashed lines and labeled by symbols (moderate and severe). "Spot" symbols are used also.

5. Icing is indicated by appropriate symbols (moderate and severe).

6. Thunderstorms are indicated by symbol .

7. Vertical extent of significant weather is indicated by bases and tops in hundreds of feet.

UP-15; MIA HIGH ALTITUDE FORECASTS

Composite surface/significant weather (500-150 mb), 500 mb, 300 mb, and composite 200 mb/tropopause prognoses from the Regional Center for Tropical Meteorology (RCTM) on a 1:20 million scale Mercator projection true at 22.5°N latitude, valid at 0000Z, 0600Z, 1200Z, and 1800Z, about ten to twelve hours after transmission time. Area covered is equator to 46°N latitude between 120°W and 50°W longitude with an inset in lower left corner covering equator to 12°S latitude between 88-80°W and 73°W longitude. For the 0600Z valid time an additional area from the central Atlantic to the African coast is attached to complete a forecast route from New York to Dakar. (See cut CA-/, appendix 16.) Significant weather, 300 mb, and 200 mb prognoses valid at 0600Z for area equator to 43°N latitude between 70°W and 5°E longitude are transmitted directly to San Juan.

Forecast Procedure

1. GUIDANCE:

The 24- and 30-hour NMC operational and guidance High Altitude numerical prognoses (see charts UP-5, UP-9, and UP-10A) are used as guidance for the portion of the Miami High Altitude prognoses north of 30°N latitude. By agreement, the 24-hour 500 mb, 300 mb, and tropopause prognoses and the 30-hour 200 mb prognosis verifying at 0000Z and 1200Z are copied over the United States.

South of 30°N latitude, the prognoses are based on the RCTM analyses and the approach to the forecast problem is subjective.

2. TIME AVAILABLE:

The numerical prognoses used as guidance are available on the High Altitude Facsimile Circuit two to three hours before transmission time for the MIA prognoses valid at 0000Z and 1200Z and about five hours before those valid at 0600Z and 1800Z.

Upper air data from the Carribean and the tropical Atlantic are not received on a strict schedule. Data received up to two and one-half hours before transmission time are considered. In data-sparse areas, later data may be considered if time permits.

A minimum of one and one-half hours is needed for completing the 500 mb, 300 mb, and 200 mb prognoses and checking for consistency. About one hour is necessary for preparing the prognoses for facsimile transmission. About forty-five minutes is required for preparation of the surface/significant weather prognosis.

3. PREPARATION:

The following procedure is used in preparation of the forecast:

a. Identifying the basic features in and near the forecast area.

b. Determining the past history of these features by inspection of preceding analyses.

c. Drawing a preliminary prognostic chart (subjective).

d. Comparing with the NMC numerical guidance for the valid time and making minor adjustments to mesh the Miami low latitude forecast with the NMC numerical mid-latitude forecast. Cases involving substantial disagreement are resolved if time permits. Aviation and area forecasters may be consulted locally and/or NMC by telephone. There is no provision for transmission of late charts. Consequently, time for consultation must be limited to permit completion of the prognostic charts by the assigned transmission time.

Philosophy of Forecast

The philosophy of most forecasters working in or with tropical and subtropical regions is based on the premise that experience and extrapolation are the most reliable tools. With the known persistence of features in these regions, a careful and well-considered analysis is of prime importance. The goal is to produce an operational chart that can be readily interpreted by dispatchers and flight crews, as well as to serve as a briefing guide for pilot briefer personnel. The primary concern is to produce charts that will depict the wind, temperature, and significant weather over a given flight route at a given time.

Depiction

1. Solid lines with arrowheads depict streamlines, generally south of 30° N latitude. To the north of 30° N, solid lines labeled by hand-stamps in geopotential decameters (thousands digit omitted at 200 mb) depict height contours. Contour intervals are 60 meters at 500 mb and 120 meters at 300 mb and 200 mb. Height centers are indicated by stamped high and low symbols.

2. Isotachs are drawn as short-dashed lines at 20 knot intervals up to 140 knots and 40 knot intervals above 140 knots labeled by stamps in knots.

   "Spot" winds are indicated by arrows with barbs, for 400 mb on the 500 mb chart and for 250 mb on the 300 mb chart.

3. Encircled "spot" temperatures are stamped on the charts in sufficient density to delineate the thermal field.

4. Heavy long-dashed lines indicate the intersections of the tropopause with constant pressure surfaces at 50 mb intervals at and below 150 mb to 400 mb, appropriately labeled in millibars, on the composite 200 mb/tropopause chart. Mean tropopause temperatures are entered in boxes along these lines.

5. Composite surface/significant weather 500-150 mb prognosis:

   a. Fronts are depicted in the usual manner (appendix 2). Isobars are drawn as solid lines labeled in millibars. Pressure centers are indicated by stamped high and low symbols.

   b. Areas of cirrus clouds and clouds associated with significant weather are enclosed by scalloped lines and labeled by eighths of coverage and type.

   c. Turbulence areas are enclosed by heavy broken lines and labeled by symbols (moderate and severe). "Spot" symbols may be used also.

   d. Icing is indicated by appropriate symbols (moderate and severe).

   e. Thunderstorms are indicated by symbol .

   f. Vertical extent of significant weather is indicated by $\frac{\text{top}}{\text{base}}$ in hundreds of feet.

UP-16; HNL HIGH ALTITUDE FORECASTS

Twenty-four hour manually produced prognoses of the composite 300 mb/200 mb charts and composite 500 mb/significant weather (surface to 150 mb) charts from the Honolulu High Altitude Forecast Office. The charts are 1:20 million Mercator projections. For the High Altitude Facsimile Circuit the areas are: cut PA-1 for the 300 mb and 200 mb charts; cut PA-2 for the 500 mb and significant weather charts (see appendix 16). For the Honolulu Radio Facsimile transmissions, all charts are for Area I as shown in appendix 45. The prognoses are for valid times of either 0000Z or 1200Z.

Forecast Procedures

1. GUIDANCE:

   Basic guidance materials used are prognostic charts from the Weather Bureau, Navy, Air Force computer unit at the Fleet Weather Central (Pearl Harbor) and NMC. (See appendices 48 and 49 for a description of computer-produced and manually-produced analyses and progs.)

2. TOOLS AVAILABLE:

   a. Surface and upper air analyses.

   b. Cloud mosaics.

   c. Nephanalyses.

   d. APT picture mosaics of the Pacific.

   e. TAFORS.

   f. 1000-250 mb thickness charts.

   g. Pilot reports.

3. PREPARATION:

   a. Significant weather prognoses-surface system positions from the most recent charts are extrapolated using basic guidance materials. Jet stream positions are given special attention. Areas of suspected or reported moderate to severe turbulence are extrapolated to fit with flow prognoses.

   b. 500 mb prognoses-the objective 500 mb prognoses are modified for changes indicated by late data. In the event no guidance material is available, the 1000-250 mb prognostic thickness chart is converted to a 1000-500 mb prognostic thickness using table 2 in appendix 46 and added to the 1000 mb prognostic

chart for a first approximation to a 500 mb prognostic chart.

The forecast streamlines are subjectively derived from the numerical 250 mb wind forecast (see appendix 49) and are adjusted further to approach climatology; both contours and streamlines are adjusted to assure proper vertical spacing. Isotherm positions are largely forecast by advection using the concept that the relative position of isotherms and contours is fairly conservative.

c. 300 mb and 200 mb prognoses-these prognostic charts are made by subjectively modifying the 250 mb prognosis in accordance with the estimated wind shear between levels (see appendix 50). Isotherm positions are largely forecast by using advection and the concept that the relative position of isotherms and contours is fairly conservative. The major subjective improvement over objective guidance materials usually comes through consideration of late data. This is particularly useful in the Tropical Pacific as AIREP data are received continuously.

Because wind patterns at 200 mb depict tropical cyclones only weakly except in very severe storm cases, tropical depressions may be overlaid by anticyclonic flow at 200 mb.

Jet stream positions are often determined from interpretation of ESSA satellite pictures, normally from the jet cloud edge shadow. Wind shears in the 300-250-200 mb layers are determined from thermal patterns and observed winds. When the tropopause is below 200 mb, the maximum shear is limited to the 300-250 mb layer.

REFERENCES:

1. Hanson, Donald A., "The Use of Meteorological Satellite Data in Analysis and Forecasting," Office of Forecast Development Technical Note No. 13, November 1963.

2. Serebreny, Sidney M., et al, "Investigation of Operational Use of Cloud Photographs from Weather Satellites in the North Pacific," Final Report U. S. Weather Bureau Contract CWB 10238, SRI Project No. 3858, Stanford Research Institute, November 1962.

3. Conover, John H., et al, "Cirrus Patterns and Related Air Motions Near Jet Streams as Derived from Photography," Journal of Meteorology, Vol. 17, No. 5, p 532, October 1960.

4. Sawyer, J. S., Ilett B., "The Distribution of Middle and High Clouds Near the Jet Streams," Meteorological Magazine, Vol. 80, No. 952, p 277, October 1951.

5. Whitney, L. F., et al, "On Locating Jet Streams From Tiros Photographs," Monthly Weather Review, Vol. 94, No. 3, pps 127-138, March 1966.

6. Anderson, R. K., et al, "The Use of Satellite Pictures in Weather Analysis and Forecasting," WMO Technical Note #75 (WMO No. 190, TP 96) 1966.

7. Riehl, Herbert, "Tropical Meteorology," p 300, McGraw-Hill, 1954.

Depiction

1. Significant weather prognoses: fronts and isobars are shown by heavy solid lines with the fronts pipped in the usual manner. Pressure centers are indicated by high and low symbols. Locations of the 0°C isotherm at 5,000 foot intervals of height are indicated by short-dashed lines which are appropriately labeled. Cloud areas are enclosed by scalloped lines and labeled by eighths of coverage and type.

   Turbulence areas are enclosed by heavy long-dashed lines and labeled by symbols (moderate and severe). "Spot" symbols are used also. Icing is indicated by appropriate symbols (moderate and severe). Thunderstorms are indicated by symbol . Vertical extent of significant weather is indicated by bases and tops in hundreds of feet.

2. 200 mb, 300 mb, and 500 mb charts: streamlines are drawn as solid lines to indicate the circulation pattern. Encircled "spot" temperatures with appropriate sign are plotted in sufficient density to delineate the thermal field. Isotachs are drawn as short-dashed lines at 20 knot intervals up to 140 knots and 40 knot intervals above above 140 knots. The 10 knot isotach is indicated also. Centers of circulation are stamped with "high or low" symbols.

UP-17; HNL 250 MB PROGNOSIS

Twenty-four hour manually produced prognosis on a 1:20 million scale Mercator chart for Area I (see appendix 45) twice daily for 0000Z and 1200Z.

Forecast Procedures

1. GUIDANCE:

   Basic guidance is the wind forecast at 250 mbs from the Weather Bureau, Navy, Air Force Computer Unit at the Fleet Weather Central, Pearl Harbor, (see appendix 49) and numerical guidance from NMC.

2. TOOLS AVAILABLE:

   a. Surface and upper air analyses.

   b. Cloud mosaics.

   c. Nephanalyses.

   d. APT picture mosaics of the Pacific.

   e. TAFORS.

   f. 1000-250 mb thickness charts.

   g. Pilot reports.

3. PREPARATION:

   The major subjective improvement usually comes through consideration of late data. This is particularly useful in the tropical Pacific as AIREP data are received continuously. Jet stream positions are often determined from interpretation of ESSA satellite pictures, normally from the jet cloud edge shadow.

Depiction

Streamlines are drawn as solid lines to indicate the circulation pattern. Encircled "spot" temperatures with appropriate sign are plotted in sufficient density to delineate the thermal field. Isotachs are drawn as short-dashed lines at 20 knot intervals up to 140 knots and 40 knot intervals above 140 knots. The 10 knot isotach is indicated also. Centers of circulation are stamped with "high" and "low" symbols.

UP-18; HNL 700 MB PROGNOSIS

Produced by hand on a 1:20 million scale Mercator chart extending from 100°E to 150°W and from the equator to 40°N (see appendix 45), twice daily for 0000Z and 1200Z. The chart is issued about 16 hours before valid time.

Forecast Procedures

1. NUMERICAL GUIDANCE:

   Prognostic charts available from the cooperative Weather Bureau, Navy, Air Force computer unit at Fleet Weather Central, Pearl Harbor, are used as basic guidance materials in the tropics. A description of these charts is given in appendix 48.

2. TOOLS AVAILABLE:

   a. Objective prognoses available from NMC and local Weather Bureau - Navy - Air Force computer center.

   b. Surface, 500, and 300 mb prognoses.

   c. 1000 - 250 mb prognostic thickness charts.

   d. Information from ESSA satellite nephanalyses and pictures.

3. PREPARATION:

   a. All available numerical forecast guidance materials are utilized.

   b. Vertical consistency of the contour and streamline pattern is maintained whenever possible.

   c. In the event no guidance material is available, the converted prognostic 1000-500 mb thickness obtained from 1000-250 mb prognostic thickness (see Table 2, appendix 46) is changed to $\frac{\text{1000-500 mb}}{2}$ thickness and added to prognostic 1000 mb chart to obtain approximate prognostic contours.

   d. The objective prognosis is modified for changes indicated by late data.

   e. The forecast streamlines in the tropical zone are subjectively derived by interpolation and extrapolation from the numerical 250 mb wind forecast and are adjusted further to approach climatology.

Depiction

Contours are drawn as solid lines for every 60 meters outside of the tropical zone (20°N to 20°S) and streamlines as solid lines in the tropical zone. Isotherms are drawn for 5°C interval but indicated by circled numbers on facsimile charts. Isotachs are drawn as dashed lines for every 20 knots or 10 knots where necessary. Winds are also indicated by barbs for 600 mb (see appendix 47).

E-1; 5-DAY MEAN OBSERVED ANALYSES

Description:

5-day mean analyses; transmitted Monday, Wednesday, and Friday; (see appendix 30).

a. 700 mb Sea level	Front half Northern Hemisphere to 50° N over Asia, 1:50 million, 700 mb (dotted lines) 200 foot interval, sea level (solid lines) 5-mb interval except dashed 2 1/2 mb interval where necessary to augment pattern.
b. Mean surface temperature departure from normal Total precipitation	Contiguous United States 1:22.5 million, temperature departure in °F for class intervals variable with time, total precipitation in inches in class intervals variable with time.

Processing Procedures

The 700 mb mean is computed from twice-daily (00Z and 12Z) 700 mb maps for the five day period. Height values are obtained from NMC's Computation Division's automatic data processing output 8 hours after observation time. 1977 equally-spaced values over the Northern Hemisphere are used for each of the 10 maps (see appendix 11).

The sea level mean is computed from twice-daily (00Z and 12Z) sea level maps for the five-day period. These daily Northern Hemisphere maps are produced by NMC's Analysis and Forecast Division (A&FD). Values are read from the maps and punched on cards for 512 equally-spaced locations over the Northern Hemisphere (see appendix 31).

The temperature mean is computed from daily maximum and minimum temperatures for the five-day period for 130 stations. Appropriate 1931-60 normals are used to obtain the departure from normal. All data used are checked for accuracy. See appendix 28 for temperature network.

The five-day precipitation totals are obtained from daily 24-hour amounts beginning 00Z two days after forecast day for 170 stations. These data have also been checked for accuracy. See appendix 29 for precipitation network.

Analysis Procedures

The 700 mb and the sea level analyses are performed by the computer and are drawn by the curve follower. Since mean data are smooth initially, the analyses are as good or better than those performed by a qualified analyst. The mean temperature map is analyzed in five classes and

the precipitation map into three general different categories depending on the local climatology of precipitation. These classes and categories are defined and described in WB Manual, Volume 3, B-30 for each month. In the analysis of the temperature map, only the 130 stations are used with an attempt to include climatologically homogeneous areas in the same class within the limits of the data. Analysis of the precipitation map considers, in addition to 170 stations, other stations in an attempt to specify all the gross features of the precipitation regime. This additional information is taken from the 24 hour precipitation map produced by NMC's Analysis and Forecast Division which includes not only Weather Bureau stations but hundreds of cooperative stations (chart AC-5).

E-2; 5-DAY MEAN FORECASTS

Description

5-day mean forecasts; transmitted Sunday, Tuesday, Thursday, for 5-day period beginning 2 days after forecast day.

a. 700 mb Sea level	Front half Northern Hemisphere to 50° N over Asia, 1:50 million, 700 mb (dotted lines) 60 meter interval, sea level (solid lines) 8-mb interval except 4-mb where necessary or in summer (see appendix 32).
b. Mean surface temperature departure from normal Total precipitation	Contiguous United States 1:22.5 million, temperature departure in °F in class intervals, total precipitation in inches in class intervals both variable with time (see appendix 33).

Forecast Procedures

1. GUIDANCE AND PREPARATION:

All prognostic charts are hand-drawn from subjective evaluation of computer products, climatological aids and other guidance as described below.

a. Mean 700 mb prog

The last observed 5-day mean 700 mb chart, based on data through 00Z on forecast day, is updated using 500 mb daily numerical progs, through 96 hours to provide estimates of the 5-day mean maps centered on forecast day and 2 days after forecast day. Thus the continuity of long-wave developments is projected into the forecast period and the problems of extending these large-scale developments two days hence (i.e., the 5-day mean map centered 4 days after forecast day) remains. An objective estimate of the mean 700 mb circulation for the desired forecast period is prepared by applying a modified barotropic model to the estimated 5-day mean map centered two days after forecast day in such a way that certain non-barotropic effects are accommodated (1).

The final 5-day mean 700 mb prog is based upon the foregoing, coupled with a consideration of the implications of such factors as new trough formation, interaction of high and low latitude wave trains, and blocking, as well as long-term evolution of circulation anomalies and climatology. The latter includes a survey of circulation evolution in past similar

situations using automated analog selection techniques.

b. Precipitation and Temperature Progs

Five-day total precipitation and mean temperature forecasts are based upon the prognostic upper-level circulation; objective predictions of temperature and precipitation derived from initial conditions and short-range numerical upper-level progs (2); expected daily evolution during the forecast period and when appropriate, consideration of analogous situations.

c. Mean Sea Level Prog

The prognostic 5-day mean sea level pressure distribution is based upon the prognostic upper level circulation, the expected temperature distribution and an objective estimate of the 5-day mean sea level pressure centered two days after forecast day. The latter is a specification of mean sea level pressure using multiple linear regression equations applied to the corresponding estimated 700 mb map (2).

Philosophy of Forecast

The Weather Bureau's approach to extended forecasting (3) is through the use of time-averaged circulation maps which filter out small-scale perturbations allowing consideration of the slowly-evolving long waves in the westerlies.

REFERENCES:

1. Namias, J., and collaborators, "Application of Numerical Methods to Extended Forecasting Practices in the United States Weather Bureau," 1958, Monthly Weather Review, Volume 86, pp. 467-476.

2. Klein, W. H., "Application of Synoptic Climatology and Short-Range Numerical Prediction to Five-Day Forecasting," U. S. Weather Bureau Research Paper No. 46, 1965, 109 pp.

3. Namias, J., "Extended Forecasting by Mean Circulation Methods," 1947, U. S. Weather Bureau.

4. Weather Bureau Manual, Volume III, Chapter B-30, Extended and Long-Range Forecasts.

Depiction

Prognostic 5-day precipitation and temperature are depicted in terms of classes. These classes are defined and described in reference (4) for the contiguous United States.

E-3; DAILY SEA-LEVEL PROGNOSES

Front half Northern Hemisphere to 50° N over Asia, 1:50 million, transmitted Sunday, Tuesday, and Thursday, daily progs valid at 1200 GMT 48, 72, 96, 120, and 144 hours after forecast day (see appendix 33).

Forecast Procedures

Early period

1. NUMERICAL GUIDANCE:

   Barotropic progs used primarily.

2. TOOLS AVAILABLE:

   a. Thermal fields including daily thickness progs and prognostic mean temperature anomalies are considered in relation to change implied in surface systems.

   b. Coordination with A&FD's latest 24-48 hour surface progs.

3. PREPARATION:

   The map series are prepared and drafted by hand. In the United States predicted precipitation conforms to the prognostic 5-day forecast.

Middle and latter part of period

1. TOOLS AND GUIDANCE AVAILABLE:

   a. 5-day mean prognostic 700 mb flow.

      Use of steering relationships. Consideration of mean vorticity patterns which are closely approximated by the prognostic height anomaly. Intensification and weakening related to the mean troughs and ridges. Evolving mean flow, rate and character of change of flow pattern important in determining shifts in principle storm tracks.

   b. 5-day mean prognostic sea-level chart.

      Location and intensity of mean centers of action provides constraints on daily map series. Distribution of sea level contours indicate probable tracks of Highs and Lows.

c. Prognostic temperature and precipitation.

Daily evolution must be consistent with these parameters. Sea level systems must reflect the temperature regime being forecast and must show reasonable ways to explain the precipitation forecast.

d. Climatological aids.

The following climatological tools cannot be used explicity but they are worthwhile when used as guidelines:

Principal tracks of cyclones and anticyclones.

Areal frequencies of cyclones and anticyclones per unit area for each month.

Frequencies of intensities of cyclones and anticyclones in various areas for bi-monthly periods.

e. Application of analogs.

A history tape of all daily sea level charts (1947-1963) for a three-month period (centered on current month) is searched for analogous situations. The cases that compare with the latest sea level chart above a certain threshold are printed out. These are further evaluated on the basis of current and prognostic 500 mb flow. If one is found that is approximately analogous, the ensuing evolution in the analog may be integrated into the daily series.

2. PREPARATION:

The map series are prepared subjectively and drafted by hand. In the United States the predicted precipitation conforms to the prognostic 5-day forecast.

Depiction

These charts portray surface fronts, High and Low systems and precipitation areas. Intermittent or continuous precipitation is indicated by hatching and showers by the standard symbol. Fronts are shown as wide solid lines without pips.

E-4; 72 HOUR PROGNOSES

The 72 hour sea-level prognoses valid at 1200 GMT 72 hours after forecast day, every 8 mb (occasionally 4 mb), 1:50 million, front half Northern Hemisphere 50° N over Asia. Daily temperature anomaly $\left(\frac{\max + \min}{2}\right)$ valid for third day after forecast day, every 4° F (occasionally 2° F), 1:22.5 million, contiguous United States. Both charts transmitted every Monday, Wednesday, Friday, and Saturday (see appendix 34).

Forecast Procedures

Sea Level Prog

1. NUMERICAL GUIDANCE:

Primary guidance is 72 hour numerical 500 mb prog valid 3 days hence. There is also an objective forecast of sea-level pressure valid at 0000 GMT forecast day plus 72 hours, prepared particularly for this forecast.

2. TOOLS AVAILABLE:

Coordination is made with A&FD's latest 24-48 hour surface progs. The analog list described in previous section (daily sea level progs, E-3) is prepared for this forecast. Climatological aids are used as in preparation of daily sea level series.

3. PREPARATION:

Forecasts are prepared subjectively and drafted by hand.

Daily Temperature Anomaly

1. NUMERICAL GUIDANCE:

Objective prediction of temperature anomalies for verifying day. These are described by Klein, Crockett, and Dunn (1).

2. TOOLS AVAILABLE:

Frontal positions and isobaric configuration of 72 hour prognostic sea level chart. Analogous situations selected for similarity to historical sea level charts or previous objective predictions of temperature anomaly. 48-hour shippers forecasts from field forecast centers.

REFERENCES:

1. Klein, Crockett, and Dunn, "Objective Prediction of Daily Surface Temperature," Techniques Development Laboratory, Report No. 1, ESSA, Weather Bureau, Washington, D. C., September 1965.

Depiction

The sea level progs show fronts, isobars and precipitation areas. Intermittent or continuous precipitation is indicated by hatching and showers by the standard shower symbol. Fronts are shown as wide solid lines. The temperature anomaly progs show lines of equal surface temperature anomaly.

E-5; AVERAGE MONTHLY WEATHER OUTLOOK

Prepared twice monthly, near the beginning and middle of the month for 30-day period beginning on first or 15th of month; the mean 700 mb chart 1:50 million abbreviated Northern Hemisphere, 30-day mean temperature anomaly and precipitation 1:22.5 million contiguous United States, and approximately 1:36 million North America.

Forecast Procedures

Prognosis of the 30-day mean circulation involves consideration of long-term evolution and recent trends; evaluation of effects of the changing season, expressed in part by estimated tendency fields; physical interpretation of expected developments in terms of the interrelationship between circulation features and surface-atmosphere interactions; and a consideration of pertinent climatology. Thus the 30-day mean circulation prognosis is a hand-drawn product resulting from consideration of kinematic, physical, and climatological indications.

The mean circulation prognosis is interpreted in terms of temperature and precipitation via specification equations which are then subjectively modified. Prevailing cyclone and anticyclone tracks are also estimated on the basis of the prognostic mean 700 mb circulation and its anomaly together with an objectively specified sea-level pressure map and the prognostic mean temperature and precipitation distribution.

Philosophy of Forecast

As in 5-day forecasting, the basic approach used by the Weather Bureau in 30-day forecasting is through time averaged circulation maps (1). Turbulence in the form of daily pressure systems is filtered out focusing attention upon the slowly evolving large-scale circulation features remaining on the 30-day mean chart. Continuity of long-wave evolution is clarified through a series of overlapping observed 30-day mean 700 mb charts prepared every 15 days, together with estimated 30-day means centered on forecast day and 5 days hence. The latter are based on available observed data, short-range numerical progs and climatology.

Changes in the 30-day mean circulation are believed due to seasonal variations in insolation interacting with the existing circulation regime to produce successive readjustments of the circulation until a relatively harmonious state is achieved.

Depiction

Prognostic 30-day precipitation and mean temperature are depicted in terms of classes whose limits are provided in the twice-monthly issues of "Average Monthly Weather Outlook." This publication also contains a statement regarding the use of the monthly outlooks. Prognostic prevailing cyclone and anticyclone tracks are shown on the mean 700 mb prog

as solid and open arrows, respectively. See appendix 35.

REFERENCES:

1. Namias, J., "Thirty-Day Forecasting: A Review of a Ten-Year Experiment," 1953, Meteorological Monographs, Volume 2, No. 6, 83 pp.

NA-1 NEPHANALYSIS

Prepared from all available data, 1:20 million polar stereographic for areas 15° N latitude to 90° N latitude and from 15° S latitude to 90° S latitude, 1:15 million Mercator from 30° N latitude to 30° S latitude.

Description

Nephanalyses are graphical depictions of the data contained in the television pictures obtained from meteorological satellites. They are prepared from all available data. Picture swaths cover the sunlit portion of the earth from North to South and are 25 to 30 degrees of longitude wide. Data is usually received from 12 to 14 orbits per day at 100 to 115 minute intervals according to the satellite being used. Pictures of any given area are taken at approximately the same time each day because the satellites are in sun synchronous orbits. Since the satellites cannot be contacted on all orbits, several orbits of data may be received during one interrogation, with a corresponding time delay.

In addition to the nephanalyses of individual orbital swaths, charts showing both the cloud patterns determined from the nephanalyses and the most nearly synoptic NMC surface analysis are being transmitted on the National Facsimile Circuit. These charts are prepared for specific areas and are scheduled for transmission at the same time daily. The areas treated in this manner are:

North Atlantic Ocean
North America and eastern North Pacific Ocean,
North Pacific Ocean

Processing Procedures

Pictures are normally stored on a tape recorder on board the satellite until the next time it is interrogated by a Command and Data Acquisition (CDA) Station. They may also be taken when the satellite is in range of a station, hence, are received immediately. The CDA stations are located at Gilmore Creek, Alaska, and Wallops Island, Virginia. The CDA stations interrogate the satellite and record the data on magnetic tape. These taped signals are then transmitted to the National Environmental Satellite Center (NESC), Suitland, Maryland, where they are converted into pictures on 35mm film. The film is developed and printed in an enlarged format using high speed photo techniques. Prior to the receipt of the pictures latitude-longitude grids are prepared by computer based on predictions of the picture times and satellite attitude. The pictures and grids are merged electronically when the 35mm film is exposed.

Analysis Procedures

1. TIME AVAILABLE:

The gridded pictures from a single orbit are available for analysis about 40 minutes after they are received at a CDA station. They are analyzed for meteorological content by a crew consisting of a shift supervisor, one meteorologist, and two meteorological technicians. They require 45 minutes to 1 hour to prepare the cloud analyses with accompanying meteorological interpretations. The chart is then traced and prepared for transmission by facsimile. The charts are transmitted in available scheduled slots according to a priority system for each circuit used. This priority is based on area covered and timeliness of data.

The nephanalyses from successive single orbits over the North Atlantic Ocean, North America, and the North Pacific Ocean are put together in a composite form. This mosaic is reviewed in conjunction with a computer produced rectified analysis to improve both the depiction and accuracy of location of the satellite data. The data are then mapped on a polar stereographic map base at 1:20 million. The cloud information is correlated with the NMC surface analysis and the 500 mb contour and vorticity analyses. The final analysis is coordinated with the NMC analysts of the Analysis and Forecast Division and adjustments are made as required.

2. TOOLS AVAILABLE:

a. Current and previous satellite photographs of area.

b. Selected examples of meteorological systems as they appear in satellite photographs.

c. Surface charts prepared at NMC and Miami.

d. Upper air charts prepared at NMC and Miami.

e. Snow Cover Chart.

f. Significant Weather Chart.

g. Radar Charts.

h. Vorticity Charts.

i. Any other pertinent charts that may apply to area being analyzed.

Philosophy of Analysis

To provide meteorologists with meteorological interpretations of satellite TV data in such a form as to allow them to use the data to confirm, improve or extend their analyses.

The purpose of the combined NESC-NMC analyses transmitted on the National Facsimile Circuit are:

1. To present the information from the satellite in a broadscale format so that it can be more easily correlated with conventional analyses at field stations.

2. To deliver current satellite data over a given area to users on a routine scheduled basis.

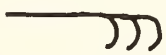
3. To give the stations having an Automatic Picture Transmission System ground station an additional satellite observation from which to obtain indications of movement and development of systems.

Depiction

1. CLOUD TYPES

Cumuliform

Apparent CUCG or CB



Cirriform

Stratiform

Stratocumuliform

2. CLOUD AMOUNT (COVERAGE)

O	Open	< 20%
MOP	Mostly Open	20% - 50%
MCO	Mostly Covered	50% - 80%
C	Covered	> 80%

3. SIZE OF FEATURES

Cloud	Size (Nautical Miles)	Open Spaces
1	0 - 30	6
2	30 - 60	7
3	60 - 90	8
4	90 - 120	9

4. BOUNDARIES

Major cloud system ———— Definite

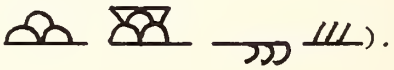
+ + + + + + + + Limit of snow or ice — — — — Indefinite

5. PATTERNS AND SYNOPTIC INTERPRETATIONS

Point toward which cloud band(s) tend to spiral.

Point in a generally open field of cumuliform clouds toward which cloud elements tend to spiral.

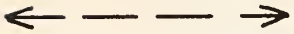
Distinct comma shaped cloud mass.

Cloud line (form may be ).

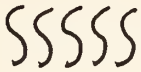
Cloud line, tenuous.

Change of element size along cloud line as indicated.

Striations

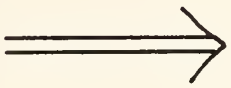


Striations, tenuous



Wave clouds (mountain or transverse)

Estimated location of the jet



Direction of Cirrus Shear

Bright (highly reflective cloud mass)

Thin

NA-1A; DIGITIZED MOSAICS

Prepared from all available data, 1:20 million polar stereographic for areas 15°N latitude to 90°N latitude and from 15°S latitude to 90°S latitude, 1:20 million Mercator from 30°N latitude to 30°S latitude.

Description

Digitized mosaics (see appendices 41, 42, 43, 44) are facsimile products with dimensions 18" wide by 23" long for Mercator Sections and 18" wide by 14" long for Polar Sections. They appear similar to newspaper half-tone photographs except they are in sepia and white shades where Alden paper is used. The difference between nephanalyses and digitized mosaics is shown in appendices 36 and 37. The digitized mosaics are cloud depictions made from television camera signals obtained from satellite passes. The television camera elements from each picture are computer processed to eliminate redundancy, adjust brightness, and add longitude and latitude information. The initial portion of each mosaic contains about one inch of seven or eight level tone wedge to be used for facsimile receiver calibration. The digitized mosaics complete the remainder of the chart. Date of the mosaic and geographical orientation are determined by the statement at the top of the transmission. The polar sections have, in addition, a mean time which refers to the geometrical center of the chart. The latitude and longitude lines are subdivided every 5 degrees. (Since the maximum resolution in the video picture is a function of the number of raster lines per total distance spanned, the selection of the number of samples along each raster line is made to correspond with the number of raster lines to maintain uniformity in the image. Thus, in the AVCS (Advanced Vidicon Camera System) which has 800 scan lines vertically, 800 samples are taken along each raster line to give an 800 X 800 array of 640,000 samples.)

Processing Procedures

Pictures are normally stored on a tape recorder on board the satellite until the next time it is interrogated by a Command and Data Acquisition (CDA) Station. They may also be taken when the satellite is in range of a station, hence, are received immediately. The CDA stations are located at Gilmore Creek, Alaska, and Wallops Island, Virginia. The CDA stations interrogate the satellite and record the data on magnetic tape. These taped signals are then transmitted to the National Environmental Satellite Center (NESC), Suitland, Maryland, where they are fed into the CDC 6600 computer for digital rectification procedures. These involve a series of complex steps to condition the signal for signal rectification and spatial rectification.

a. Signal Rectification

This process begins by removing certain non-earth viewing samples at the edge of each frame. Additional cropping is done within

each frame to minimize the sun glint problems and to avoid using imagery having poor brightness response. Noise and reference marks are removed and interpolative video information is inserted. The data are further conditioned by a brightness calibration process which includes:

1) correction for vignetting due to optical properties of the lens system, and non-linearities within the vidicon tube and associated electronics system,

2) illumination variation due to solar angle.

The raw video data ranges in grey scale from 0 to 63 which is compressed to a 0-14 scale in a normalizing procedure to make the grey scale display more uniform. Brightness is normalized for each frame in order to provide a reference level for establishing an uniform brightness response. The cropping and brightness normalizing minimizes small discontinuities that appear where frames are joined and/or at the adjoining edges of the passes. These are usually very small and hardly noticeable.

b. Spatial Rectification

The video data are now ready for transportation to arrays oriented to map projection. The actual rectification process is, in effect, the assignment of raster elements to earth coordinates,for replotting latitude and longitude values are computed for approximately every 60 miles N.M. (at the equator) for data derived from the raster lines or every 32nd sampling point along the raster line and every 32nd raster line. Once the earth coordinates have been identified and assigned within the machine grid, the intervening intervals between grid points are assumed to be linear. The resulting errors are small compared to uncertainities and errors found elsewhere in the system. In the next step, the video data are stretched or distorted over the large arrays (4096 grid squares for every NWP grid square) to fit a particular map projection. A linear map resolution is approximately 2 N.M. at the equator and 4 N.M. at the pole. The size of the received copy and the number of lines per inch reproduced by the facsimile recorders determines the actual resolution of the received mosaics. A map scale of 1:15 M as received on the Alden 19" facsimile recorder approximates the true resolution of the original data; for a 1:20 M the resolution is lower.

REFERENCE:

1. Bristor, C. L., Callicott, W. M., and Bradford, R. E., "Operational Processing of Satellite Cloud Pictures by Computer", MWR Vol 94, No. 8, August 1966, pp. 515-527.

NA-2; SATELLITE ICE CHART

Satellite Ice Reconnaissance Chart of the Great Lakes area at 1:2 million scale for transmission (see appendix 51 at 1240Z, 1-3 times per week depending upon cloud cover, satellite performance and whether or not significant changes in coverage have been observed.

Processing Procedures

Operational prints (5" X 7") received from each satellite pass over Great Lakes region are examined daily (or as often as region is photographed) for evidence of ice in the Lakes. When ice is detected, enlarged (8" X 10") gridded photographs are obtained and analyzed. Composite charts are prepared from pictures acquired over a 1-3 day period and transmitted if changes are significant from last chart sent.

Analysis Procedures

Chart shows ice boundaries, and a four stage breakdown of apparent ice concentration. The fraction x/y (i.e., relative brightness/apparent concentration) is used by the analyst as a means of expressing as much information about satellite-observed ice characteristics as possible without stating ice age, thickness or type. In certain cases, however, the analyst will indicate in plain language when the ice appears to consist of small or large floes or ice fields and when and where cracks, leads, or other open water features appear.

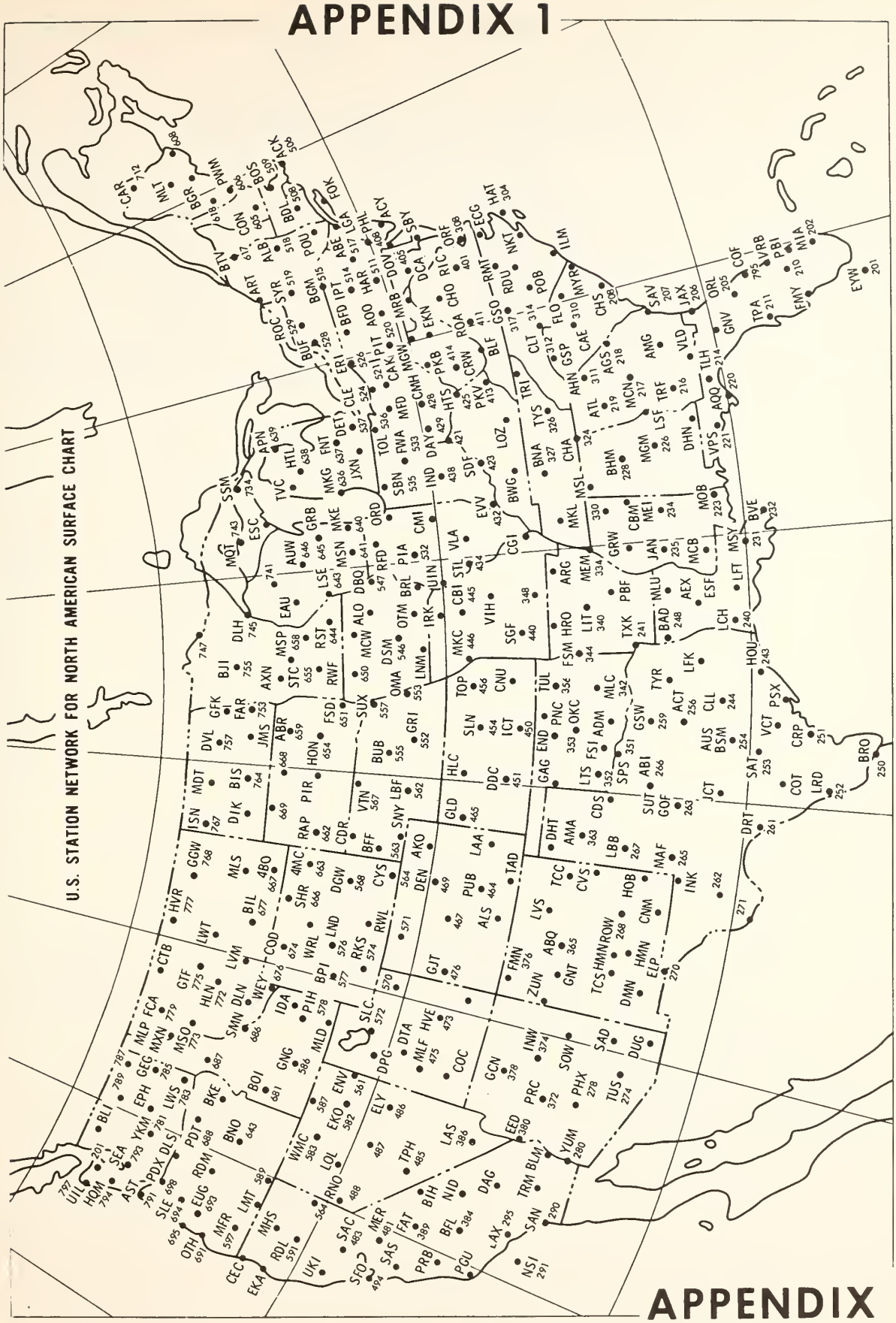
Philosophy of Analysis

Charts are intended to complement or supplement, where feasible, surface and aerial observations of ice in the Great Lakes on an operational basis. As a research tool they are intended to depict total ice cover over the entire lakes region at one-to-three day intervals, if such coverage is obtainable.

Depiction

Non-standard notation to depict ice concentration varying from 1-10 tenths is to be used. See legend of attached chart in appendix 51.

APPENDIX 1

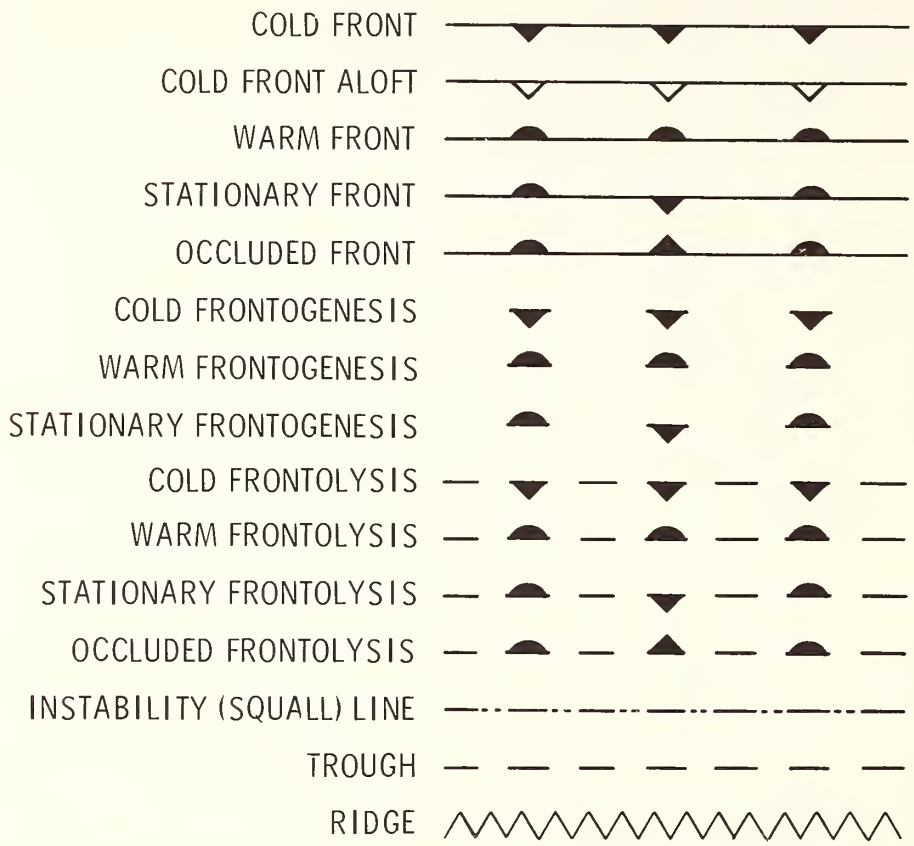


APPENDIX 1

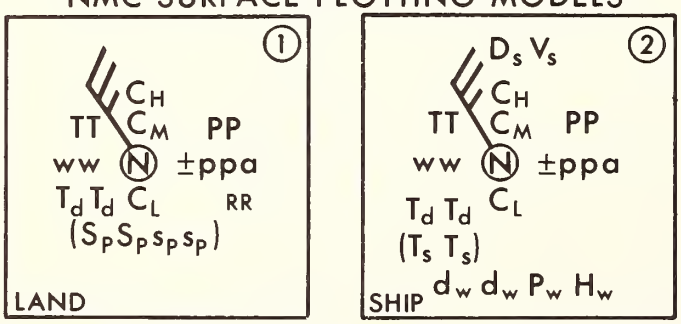
Appendix 2

WBAN WEATHER ANALYSIS SYMBOLS

These are the symbols most generally used by the National Meteorological Center although there are occasionally others.



NMC SURFACE PLOTTING MODELS



Appendix 2

U. S. Dept. of Commerce
WEATHER BUREAU

ABRIDGED FORM OF U. S. WEATHER ANALYSIS CODE

-Based on International Analysis Code (IAC)-

Effective Jan. 1, 1949

IDENTIFICATION
- 10001 (analysis)
- 65556 (prognosis)

FORM OF POINT + POSITION GRPS.
- 33366 (yyyyy = $ttiO_1s_1$) or
- 33388 (yyyyy = $QL_aL_aL_oL_o$)

DATE - TIME GMT
- $OYYG_cG_c$

PROG. PERIOD IN HOURS FROM G_cG_c
- $000G_pG_p$ (prog. only)

TYPE OF ANALYSIS
- 82228 (constant pressure only)

VALUE DESIGNATOR
- $00x_3x_3x_3$ (e.g. 850 mb. chart $x_3x_3x_3$ = 850)

PRESSURE SYSTEM SECTION INDICATOR (1)
- 99900

PRESSURE SYSTEM GROUP (2)
- $8P_tP_cPP$ or
- $8h_th_th_h$

P_t - Pressure Type (h_t - topography system)
0 - Complex LOW
1 - LOW
2 - Secondary
3 - Trough
4 - Wave
5 - HIGH
6 - Area of uniform pressure (or height)
7 - Ridge
8 - Col
9 - Tropical storm

P_c - Pressure Characteristic (h_c - character of topography system)
0 - No specification
1 - LOW filling or HIGH weakening
2 - Little change
3 - LOW deepening or HIGH intensifying
4 - Complex
5 - Forming or existence suspected (cyclogenesis or anticyclogenesis)
6 - Filling or weakening but not disappearing
7 - General rise of pressure (or height)
8 - General fall of pressure (or height)
9 - Position doubtful

PP - Pressure on a constant level surface in tens and units of millibars.

hh - Height above mean sea level in hundreds and tens of geopotential feet.

LOCATION OF CENTER
- yyyyy .....

MOVEMENT GROUP
- $md_sd_sf_sf_s$

Movement indicator figure
0 - No specification
1 - Stationary
2 - Little change
3 - Becoming stationary
4 - Retarding
5 - Curving to left
6 - Recurving
7 - Accelerating
8 - Curving to right
9 - Expected to recurve

Direction in tens of degrees TOWARD which system or front is moving.

Speed, in knots, of system, front or area.

BREAK GROUP (1)
- 00000

FRONTAL ANALYSIS SECTION INDICATOR (1)
- 99911

FRONT GROUP (3)
- $66F_tF_tF_c$

LOCATION FIRST POINT (4)
- yyyyy

LOCATION SECOND POINT (4)
- yyyyy .....

Frontal type
0 - Quasi-stationary
1 - Warm front
2 - Warm occlusion
3 - Upper warm front
4 - Cold front
5 - Cold occlusion
6 - Upper cold front
7 - Instability line
8 - Intertropical front
9 - Occlusion

Frontal Intensity
0 - No specification
1 - Weak, decreasing (including frontolysis)
2 - Weak, little or no change
3 - Weak, increasing (including frontogenesis)
4 - Mdt., decreasing
5 - Mdt., little or no change
6 - Mdt., increasing
7 - Strong, decreasing
8 - Strong, little or no change
9 - Strong, increasing

Frontal Characteristic
0 - No specification
1 - Frontal activity area decreasing
2 - Frontal activity area little change
3 - Frontal activity area increasing
4 - Intertropical
5 - Forming or existence suspected
6 - Quasi-stationary
7 - With waves
8 - Diffuse
9 - Position doubtful

- $\cdot iiiD_1s_1$

Station number

Direction from station indicated
0 - at the point
1 - NE 5 - SW
2 - E 6 - W
3 - SE 7 - NW
4 - S 8 - N

Distance in tens of miles from station; if s_1 is 110 miles or more, the $iiiD_1s_1$ group is preceded by a group $00s_200$ where s_2 indicates the hundreds of miles to be added to s_1.

- $\cdot QL_aL_aL_oL_o$

Octant of globe North latitude
0 - 0° to 60°W Longitude
1 - 60°W to 180° "
2 - 180° to 90° E "
3 - 60°E to 0° "

Latitude and longitude to nearest whole degree. Group $OOOL_aL_o$ may be added, with L_a and L_o giving tenths of degrees of latitude and longitude respectively.

ISOPLETH SECTION INDICATOR (1)
- 99922

ISOBAR OR CONTOUR INDICATOR (5)
- 40hhh (contour)
- 42%sTT (isotherm °C)
- 44PPP (isobar)

LOCATION FIRST POINT (4)
- yyyyy

LOCATION SECOND POINT (4)
- yyyyy .....

BREAK GROUP (1)
- 00000

AIR MASS SECTION INDICATOR (1)
- 99933

AIR MASS GROUP (6)
- $33M_hM_sM_t$

LOCATION OF CENTER
- yyyyy .....

BREAK GROUP (1)
- 00000

Character of air mass
0 - Indeterminate
1 - Continental (c)
2 - Maritime (m)

General source region
0 - Indeterminate
1 - Arctic (A)
2 - Polar (P)
3 - Tropical (T)
4 - Equatorial (E)
5 - Superior (S)

Temperature relative to surface
0 - No specification
1 - 4 - 7 Indeterminate
2 - 5 - 8 Cold (k)
3 - 6 - 9 Warm(w)

(See note 7 for explanation.)

NOTES

(1) Section indicators (99900, 99911, etc.) are used only once in each section. Break groups (00000) are used to separate individual fronts, isobars, etc., when necessary.

(2) Given for each pressure system, or topography system, present.

(3) Given for each front present. The group 22266 (meaning "changing to") will be used, followed by another $66F_tF_tF_c$ group, when required to show a front of changing type or other specification. (The group 22266 is for U.S use only; it is not included in IAC.)

(4) As many location groups are given as are necessary to locate the line.

(5) Given for each significant isobar, contour or other isopleth; for isotherms 420TT is used for temperatures above zero, and 425TT for temperatures below zero. When e_1 is coded 1, dew point isopleth is indicated, when e_1 is 5, mixing ratio isopleth is indicated.

(6) Given for each air mass present.

(7) (a) When code figures 1, 2, or 3 are used: if not followed by another air mass group, means only one air mass present. If followed by another air mass group means "mixed" with air mass described in second group.

(b) When code figures 4, 5, or 6 are used, the air mass group will be followed by another air mass group meaning "above" the air mass described in the second group.

(c) When code figures 7, 8, and 9 are used, the air mass group will be followed by another air mass group meaning "transitional" or "becoming" the air mass described in the second group.

(8) Indicator group 19191 designates end of message.

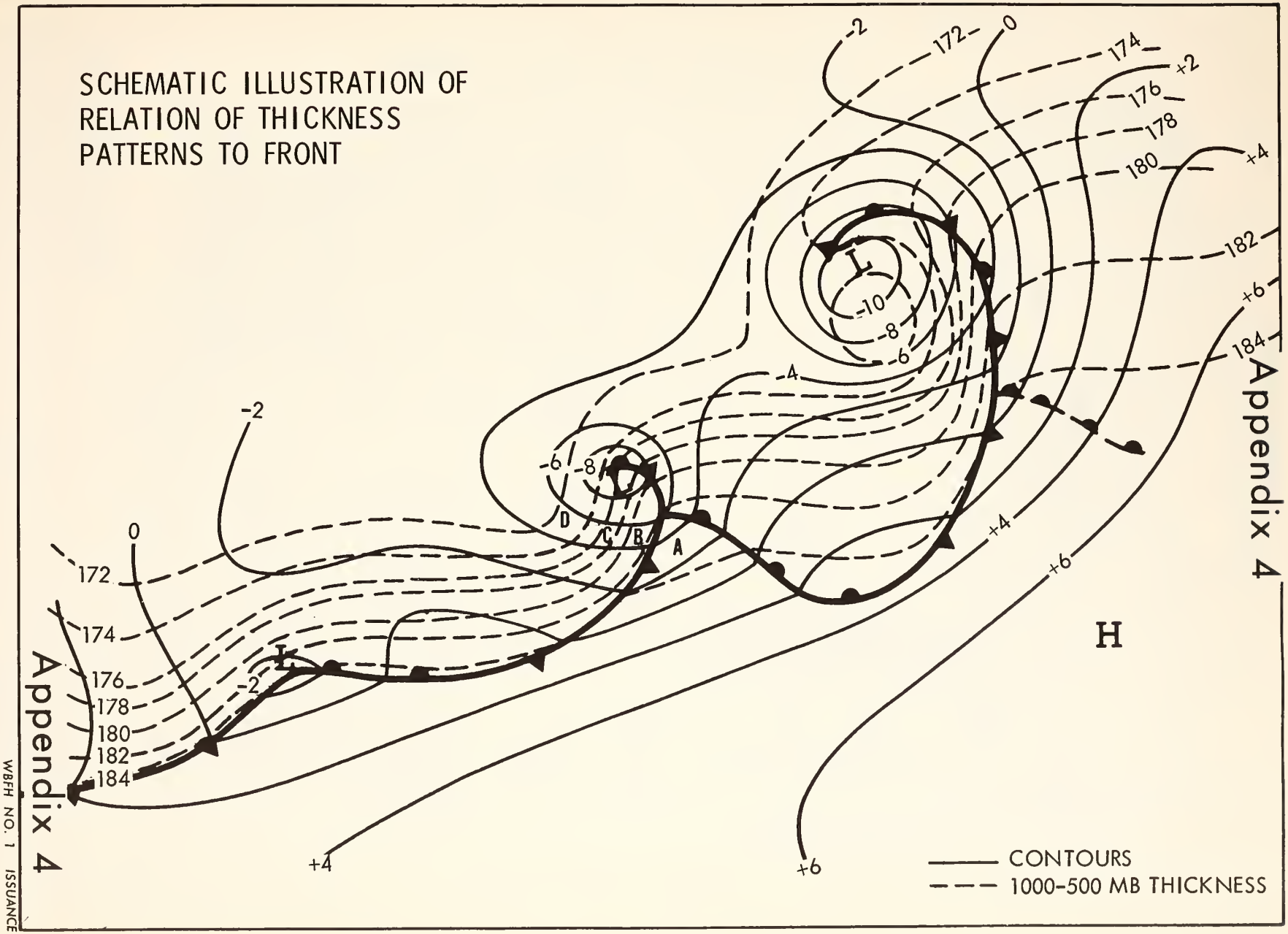
Corrections will begin with the groups 11133 $OYYG_cG_c$ followed by the corrected data, ending with the group 18181. Date and time will be those of the analysis being corrected.

For complete form see: U. S Weather Analysis Code.

APPENDIX 3

APPENDIX 3

WBFH NO. 1 ISSUANCE 67-1 10-1-67



Appendix 4

Appendix 4

Appendix 5
WEATHER DEPICTION GUIDE

SYMBOLIC SECTION

STATION MODEL

(1) Significant Weather

(2) Visibility — 3 RF — (3) Total sky-cover

15

(4) Ceiling height / or height of lowest scattered layer

(1) SIGNIFICANT WEATHER

	PLOT
A	A
TRW	TR
SW, SP	SW
RW	RW
E	E
S, SG, IC	S
ZR	ZR
R	R
ZL	ZL
L	L

Always plotted, but not more than two types.

F, GF, IF	F

Not plotted when two types of precip reptd.

H	H
K	K
BS	BS
BD	BD

Not plotted when any precip reptd. Plotted only when vis is 6 mi. or less.

NOTE

IT SHOULD SELDOM BE NECESSARY TO USE MORE THAN TWO LETTERS TO PLOT SIG-NIFICANT WEATHER, IF THE GUIDE IS USED CORRECTLY. GIVE PRECEDENCE TO THE HIGHEST INT. SFC. CODE NUMBER, IN GENER-AL THE ORDER OF IMPORTANCE IS

INSTABILITY	A , T , W
SOLID OR FREEZING PRECIP	E , S , Z
LIQUID PRECIP	R , L
OTHER OBSTRUCTIONS	F , H , K

ONLY WEATHER OCURRING AT THE STATION, AT THE TIME OF OBSERVATION WILL BE PLOTTED, DISREGARD + & — AND FINE DEFINITIONS (GRANULAR, NEEDLES AND PELLETS, ETC)

(2) VISIBILITY

Values over 6 miles will not be plotted.

(3) TOTAL SKY-COVER

○	CLEAR
◔	SCATTERED
◕	BROKEN
◑	BINOVC
●	OVERCAST
⊗	OBSCURED

NOTE- When -X is reported for total sky-cover ⊗ will be plotted, the absence of a ceiling height will show that the obscuration is thin or partial.

(4) CEILING HEIGHT

All ceiling heights will be plotted. When total sky cover is ◔ the height of lowest sctd layer is plotted.

DIGITAL SECTION

CLASS

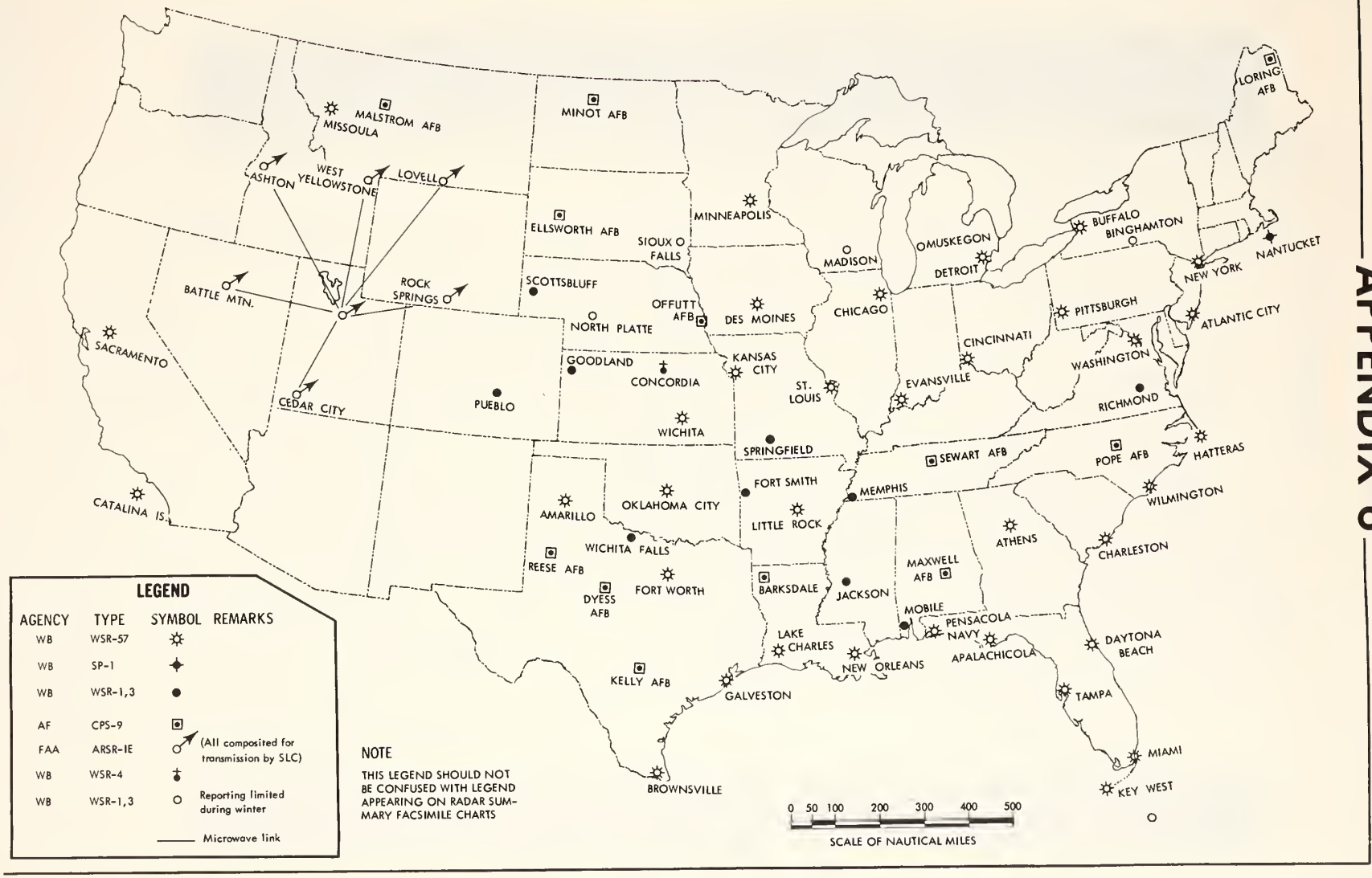
1. Ceiling less than 1000 feet and or visibility less than 3 miles.
2. Ceiling 1000 to 5000 feet and visibility 3 miles or more.

Nothing is plotted when visibility is 3 miles or more and ceiling is above 5000 feet.

IMPORTANT: Clouds topping ridges should always be plotted

Appendix 5

NATIONAL WEATHER RADAR REPORTING NETWORK



LEGEND

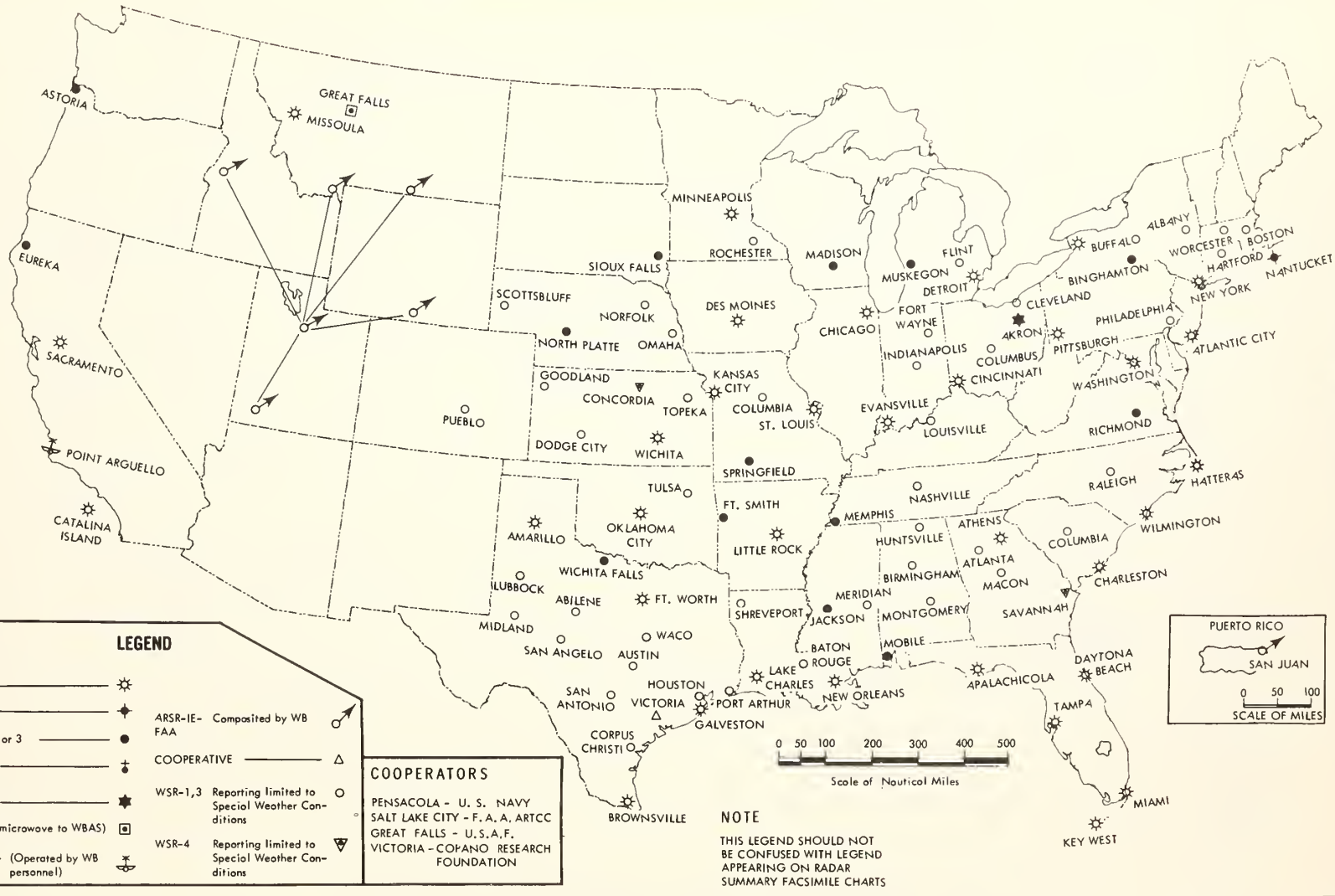
AGENCY	TYPE	SYMBOL	REMARKS
WB	WSR-57	☼	
WB	SP-1	✦	
WB	WSR-1,3	●	
AF	CPS-9	⊡	
FAA	ARSR-1E	○	(All composited for transmission by SLC)
WB	WSR-4	‡	
WB	WSR-1,3	○	Reporting limited during winter
		——	Microwave link

NOTE

THIS LEGEND SHOULD NOT BE CONFUSED WITH LEGEND APPEARING ON RADAR SUMMARY FACSIMILE CHARTS

APPENDIX 7

WEATHER BUREAU RADAR NETWORK



LEGEND

- WSR-57
- SP-1
- WSR-1, 1A or 3
- WSR-4
- DECCA 41
- AF CPS-9 (microwave to WBAS)
- NAVY FPS-6B (Operated by WB personnel)
- ARSR-IE-FAA Composited by WB
- COOPERATIVE
- WSR-1,3 Reporting limited to Special Weather Conditions
- WSR-4 Reporting limited to Special Weather Conditions

COOPERATORS

PENSACOLA - U. S. NAVY
SALT LAKE CITY - F. A. A. ARTCC
GREAT FALLS - U.S.A.F.
VICTORIA - COPANO RESEARCH FOUNDATION

NOTE

THIS LEGEND SHOULD NOT BE CONFUSED WITH LEGEND APPEARING ON RADAR SUMMARY FACSIMILE CHARTS

APPENDIX 7

APPENDIX 8

U. S. DEPARTMENT OF COMMERCE
ESSA

EXPLANATION OF RADAR SUMMARY CHART

- line of echoes
- area of echoes
- cellular echoes predominate in area
- stratified echoes predominate in area
- mixed cellular and stratified echoes in area
- over .9 coverage
- .6 to .9 coverage
- .1 to .5 coverage
- less than .1 coverage

Cellular and stratified symbols are used in conjunction with coverage symbols. For example means the broken echo pattern consists mainly of cellular echoes.

- strong or very strong cell identified by one station
- strong or very strong cell identified by long range interceptions of two or more stations

TYPE OF SURFACE WEATHER ASSOCIATED WITH ECHO

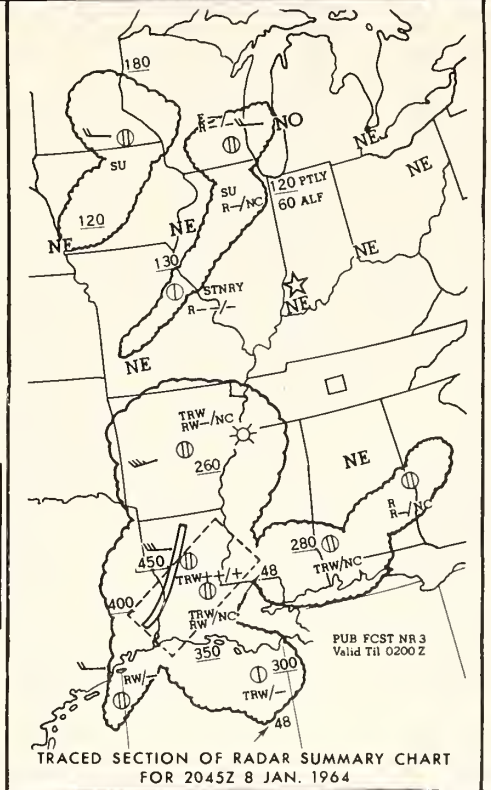
- R Rain
- RW Rain Showers
- S Snow
- E Sleet
- SW Snow Showers
- L Drizzle
- T Thunderstorm

LEGEND

Type of Radar	Symbol
WSR 57-FPS 41	☆
WSR 1,3,&4	☼
CPS 9	□
SP 1	△

INTENSITY OF PRECIPITATION

- — very light
- — light
- No Sign moderate
- + heavy
- ++ very heavy usually associated with severe weather
- U Unknown



TRACED SECTION OF RADAR SUMMARY CHART FOR 2045Z 8 JAN. 1964

INTENSITY TENDENCY OF ECHO

- + increasing
- + — increasing slowly
- + + increasing rapidly
- — decreasing
- — — decreasing slowly
- —+ decreasing rapidly
- NC no change

Note: the intensity tendency symbol follows the intensity of the precipitation symbol and is preceded by a slash.

For example, TRW +/+— means that thunderstorms and heavy rain showers are occurring with an echo that is increasing slowly in intensity.

HEIGHT IN HUNDREDS OF FEET MSL

- hhh height of echo tops
- hhh maximum height of echo tops
- hhh height of echo bases
- hhh height of melting level

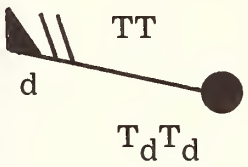
140(Top) / 100(Base) echo layer aloft heights in hundreds of feet MSL. If layers aloft occur with other echoes, these heights will be preceded by the words partly aloft.

- VV cell movement with speed in knots
- area or line movement (10 kts per barb)
- NE no echo — equipment operating but no echoes observed
- NA observation not available
- NO equipment not operating
- OM equipment out for maintenance

Area of "AVIATION SEVERE WEATHER FORECAST", with entry of no. and valid time. When a public severe weather forecast has been issued, the lines defining the area are dashed

Appendix 9

SUMMARY OF ABBREVIATED WMO MODEL FOR PLOTTING UPPER AIR DATA



HHH — Constant pressure surface height, in meters at 1000 mb through 700 mb, and decameters at 500 mb and higher pressure surfaces.

TT — Temperature in whole degrees Celsius.

T_dT_d — Dewpoint temperature in whole degrees Celsius.

d — Wind direction indicator, to 36 compass points.

NOTE: On the 850, 700, and 500 mb charts the station circle is blacked-in when the temperature-dewpoint spread is 5° or less. less.

SUMMARY OF INSTRUCTIONS FOR PLOTTING AIREP DATA BY HAND

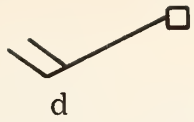
All AIREP reports will be plotted which:

(1) report wind or temperature.
(2) are within three hours of chart time.
(3) fit the altitude limits for a constant pressure chart.

Limits	Constant Pressure Level	Standard Height (Tens of feet or meters)	
8,000-12,000 ft.	700 mb	988 ft.	301 meters
16,000-20,000 ft.	500 mb	1829 ft.	557 meters
27,000-35,000 ft.	300 mb	3006 ft.	916 meters
36,000-40,000 ft.	200 mb	3866 ft.	1178 meters

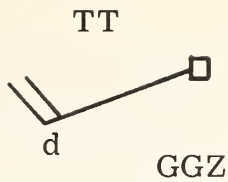
Appendix 9

STATION MODELS



Direction and force of mean wind plotted at mean wind position.

OR



GGZ Time of report to nearest hour

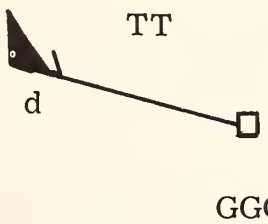
hh Altitude of aircraft in thousands of feet

HHH Height of constant pressure level derived from D value plotted at reported present position in decameters

SUMMARY OF INSTRUCTIONS FOR PLOTTING
OF WEATHER RECONNAISSANCE DATA BY HAND

All reports are plotted on constant pressure chart nearest the flight level for all times, plus or minus 6 hours from the synoptic hour.

STATION MODEL



GGGGZ Time of report to nearest minute.

HHH Height of constant pressure level in decameters.

d Wind direction to 36 compass points.

Reports are plotted at position given.

Appendix 10

SUMMARY OF INSTRUCTIONS FOR EDITING AND CODING AIREP REPORTS FOR USE IN COMPUTER ANALYSIS

1. The following Weather Bureau field offices are editing and coding AIREP data into bulletin form (UANT & UAPA) for transmission to Suitland in time for the observation-plus-3+25-hour data cut-off.

   Anchorage Int'l Airport (approximately north of 40° N, northern Pacific, Alaska, and Polar)
   Kennedy Int'l Airport for North Atlantic (north of 40° N)
   San Juan Int'l Airport for North Atlantic (south of 40° N)
   San Francisco Int'l Airport for its High Altitude Area (eastern Pac.)
   Honolulu Int'l Airport for its High Altitude Area (central Pac.)

2. AIREPS reporting ± 3 hours of 0000Z and 1200Z for all areas north of 20° N. For areas south of 20° N it is 0500Z through 1700Z for 1200Z, from 1700Z through 0500Z for 0000Z. The AIREPS are selected by the duty forecasters at these 5 stations, using the following criteria:

   a. Compatibility with the latest appropriate constant pressure analysis.

   b. Location of more than 5° latitude from an ocean vessel report (unless AIREP shows a significant variation in wind temperature, etc., from that at the O.S.V.)

   c. Reporting of both height (D-value) and wind information, if possible, since the computer analysis program gives most weight to a combined report. A wind alone will get little weight in the present analysis program.

   d. Fit into altitude limits for constant pressure analyses, as follows:

Flight Level	Analysis
3,900 to 6,000 ft.	850 mb
8,000 to 12,000 ft.	700 mb
16,000 to 20,000 ft.	500 mb
21,000 to 25,000 ft.	400 mb
28,000 to 33,900 ft.	300 mb
34,000 to 38,400 ft.	250 mb
38,500 to 42,800 ft.	200 mb
42,900 to 46,000 ft.	150 mb
51,900 to 55,100 ft.	100 mb

Appendix 10

3. A special WMO code is used to transmit the bulletin in the following symbolic form:

CC $YQL_aL_aL_a$ $L_oL_oL_o$ GGgg $h_xh_xh_xDH_z$ ddfff $(QL_aL_aL_oL_o)$ (STT HHH)

where:

CC = Message identifier letters specifying the report following is an AIREP coded in this numerical form. The double letters "CC" are always included in each individual report in the position shown in the symbolic form.

Y = Day of the week (according to GMT) on which the AIREP was made.

Q = Octant of the globe.

$L_aL_aL_a$ = Latitude in tenths of a degree of the point of observation.

$L_oL_oL_o$ = Longitude in tenths of a degree of the point of observation. (The hundreds digit is omitted for longitudes 100° to 180°).

GGgg = Time of observation in hours and minutes, GMT.

$h_xh_xh_x$ = Altitude of the aircraft, in hundreds of feet, at the time of observation (i.e., ICAO flight level number).

D = Type of wind being reported.

H_z = Hazardous phenomena encountered.

dd = Wind direction, in tens of degrees, at the flight level.

fff = Wind speed in knots at the flight level.

L_aL_a = Latitude in whole degrees.

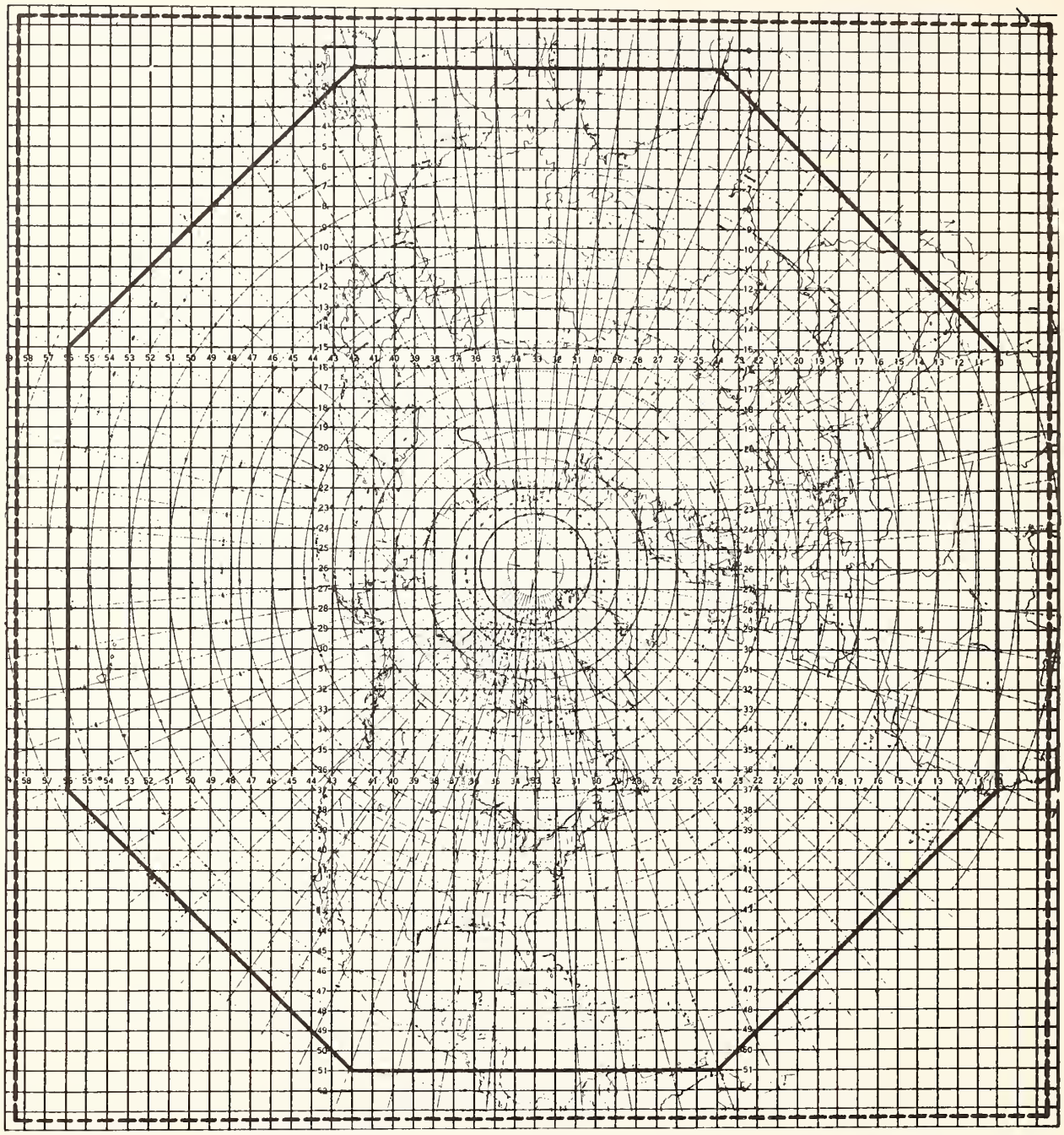
L_oL_o = Longitude in whole degrees (i.e., the hundreds digit is omitted for longitudes 100° to 180°).

S = Indicator figure specifying the type of temperature and height data which follow and whether the temperature is above or below 0°C.

TT = Observed temperature of the free air, or temperature reduced to the nearest standard isobaric surface, in whole degrees Celsius.

HHH = D-value in decameters, or computed height of the nearest standard isobaric surface in decameters (i.e., the tens of thousands digit is omitted).

Appendix 11



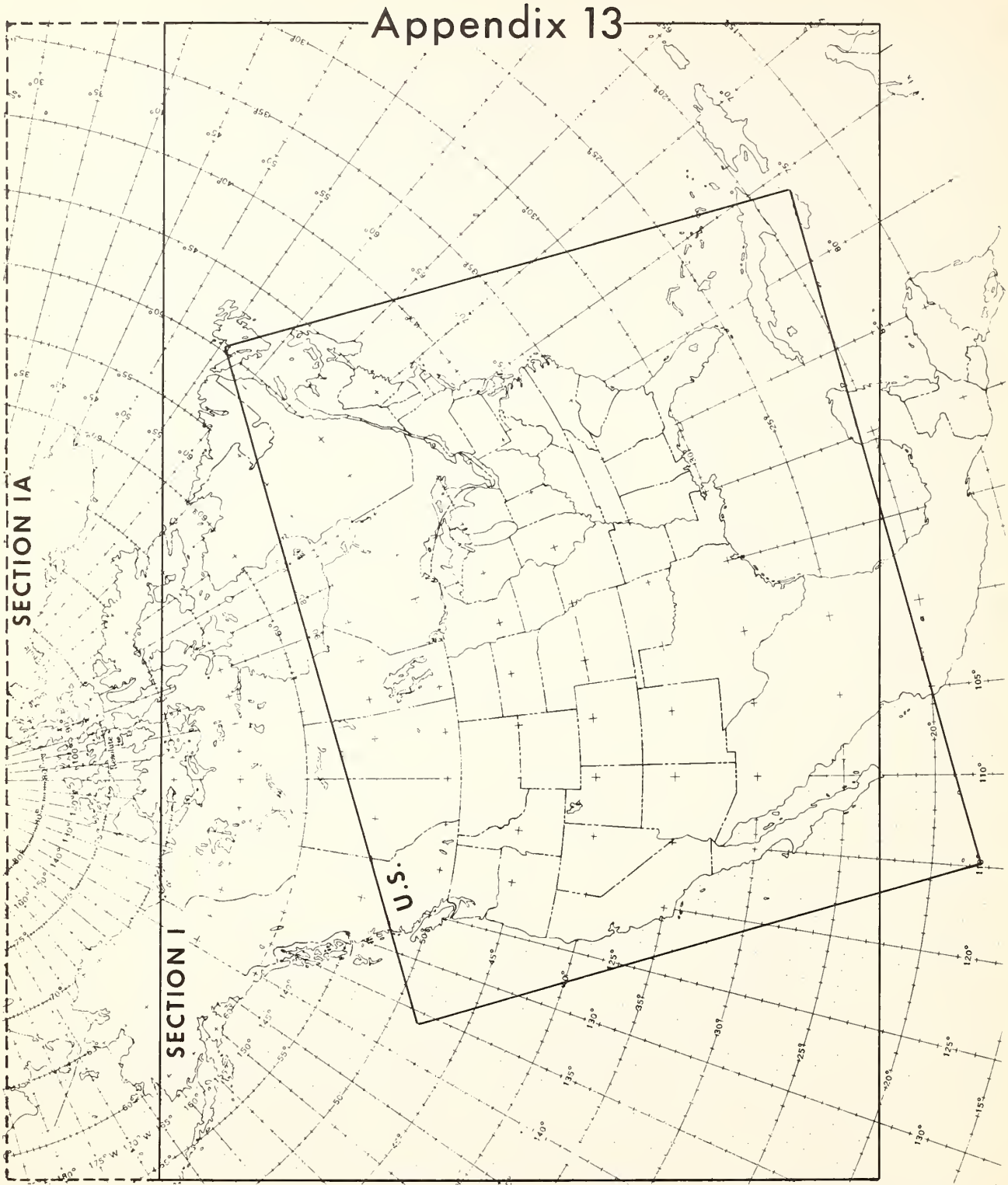
Appendix 11

METHODS OF OBTAINING THE FIRST - GUESS FIELDS
300 MB TO 10 MB

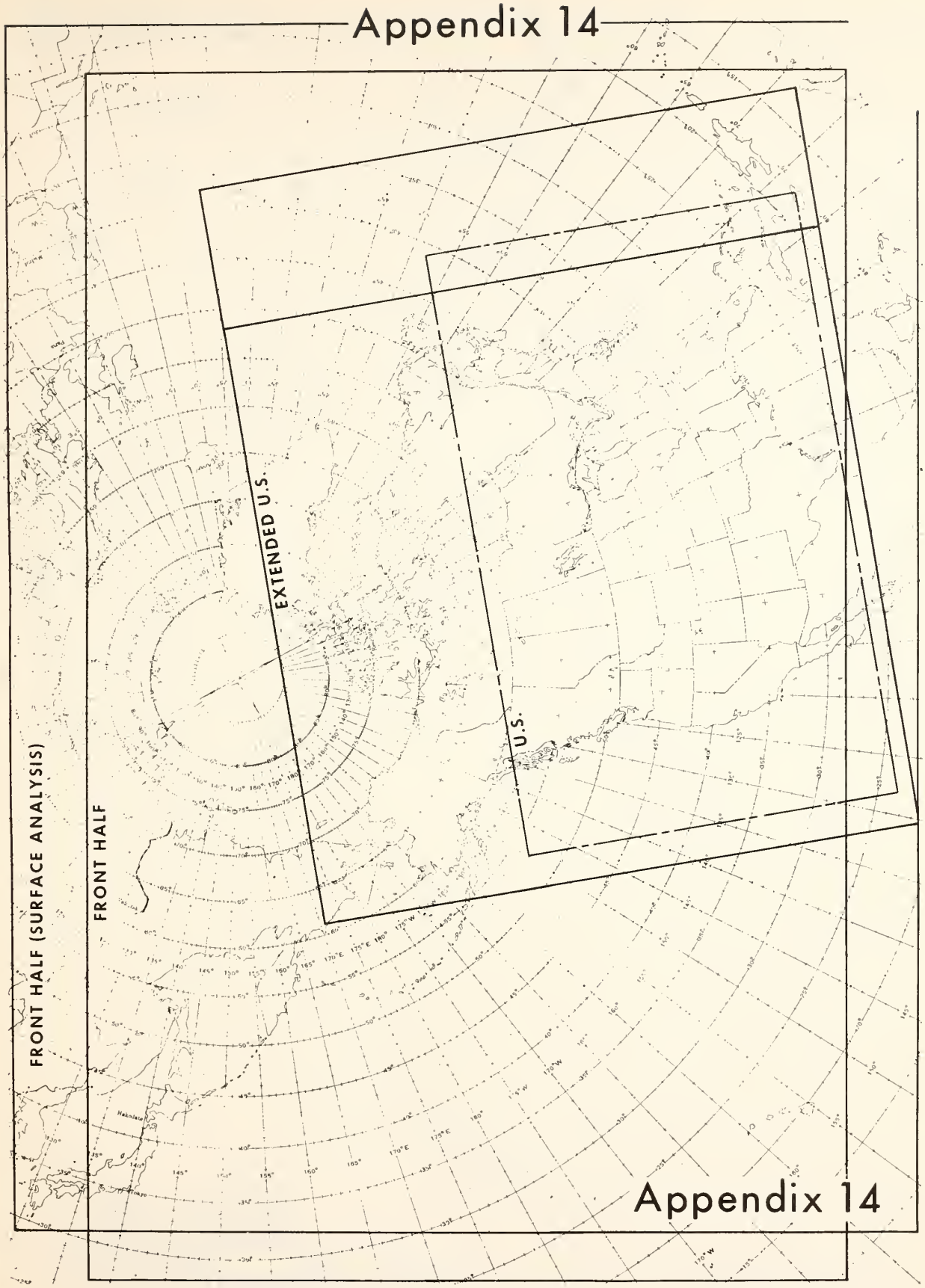
Level & Parameter	DESCRIPTION
300 mb T'	Statistical regression equation of form: ($T'_{300}=a + b\,T^{oo}_{700} + c\,T^{oo}_{500} + dZ^{oo}_{500} + eZ'_{300}$)
300 mb Z'	Corrected Z^{12}_{300} ($Z'_{300} = Z^{12}_{300} + Z^{oo}_{500} - Z^{12}_{500}$)
200 mb T'	Statistical regression equation using predictors: T^{oo}_{500}, T^{oo}_{300}, Z^{oo}_{300}, and Z'_{200}
200 mb Z'	Corrected Z^{12}_{200} ($Z'_{200} = Z^{12}_{200} + Z^{oo}_{300} - Z^{12}_{300}$)
100 mb T'	U. S. Navy family of regression equations using predictors: T^{oo}_{200}, and Z^{oo}_{200}
100 mb Z'	" " " " " " " " " " "
150 mb T'	Statistical regression equation using predictors: T^{oo}_{200}, T^{oo}_{100}, Z^{oo}_{200}, and Z^{oo}_{100}
150 mb Z'	" " " " " T^{oo}_{200}, Z^{oo}_{200}, and Z^{oo}_{100}
50 mb T' and Z'	U. S. Navy families of regression equations using predictors: T^{oo}_{200}, Z^{oo}_{100},
30 mb T' and Z'	" " " " " " " " " " T^{oo}_{50}, Z^{oo}_{50},
10 mb T' and Z'	NMC Upper Air Branch (UAB) " " " " " T^{oo}_{30}, Z^{oo}_{30},
300 to 10 mb Wind	Geostrophic wind from the analyzed height field

PARAMETERS:

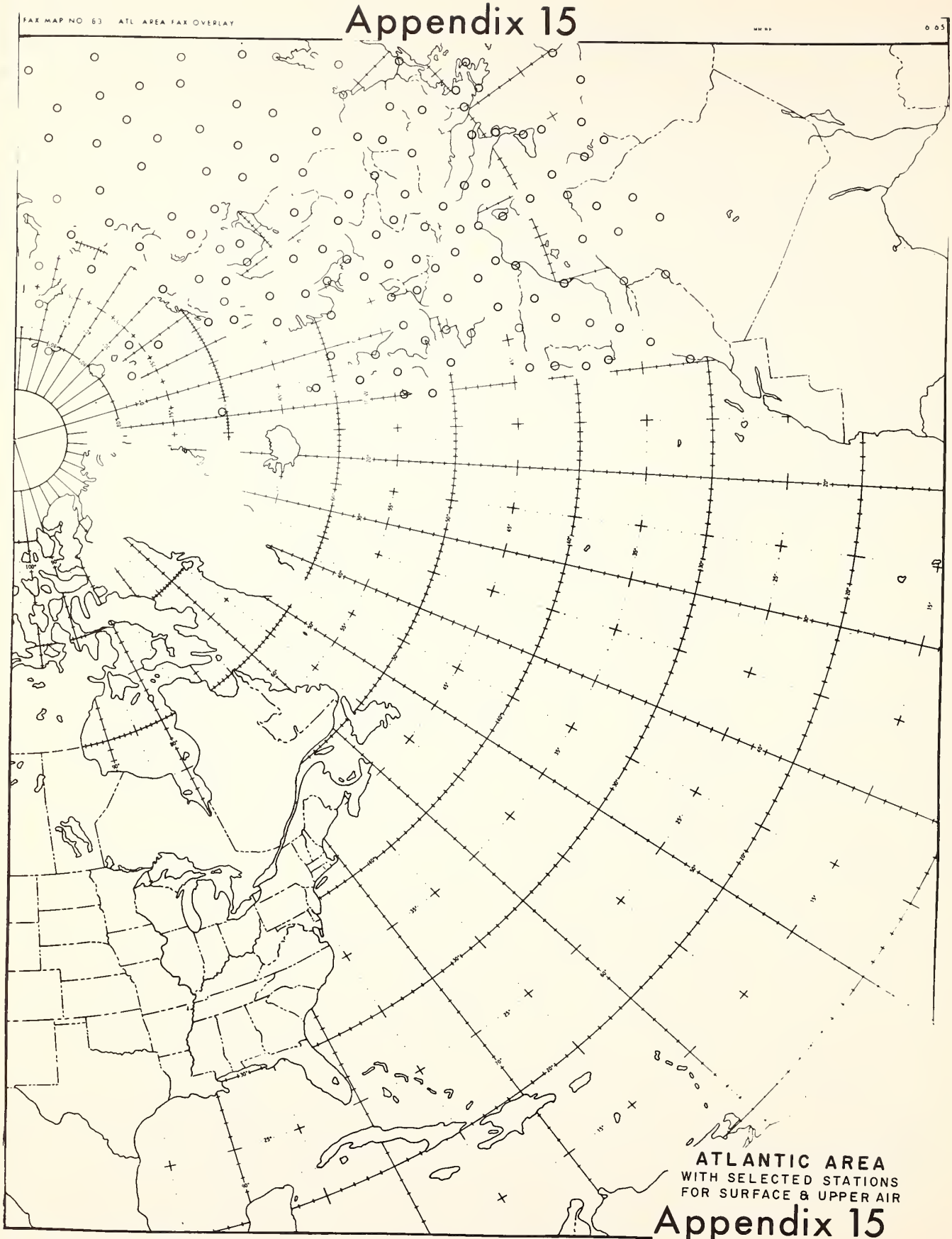
Z^1 = Height Guess Value
T^1 = Temperature Guess Value
Z^{12}_{200} = 12-Hr Height Prog at 200 MB
Z^{oo}_{300} = Initial Height at 300 MB
Z^1_{200} = Guess Height at 200 MB etc.



Appendix 13



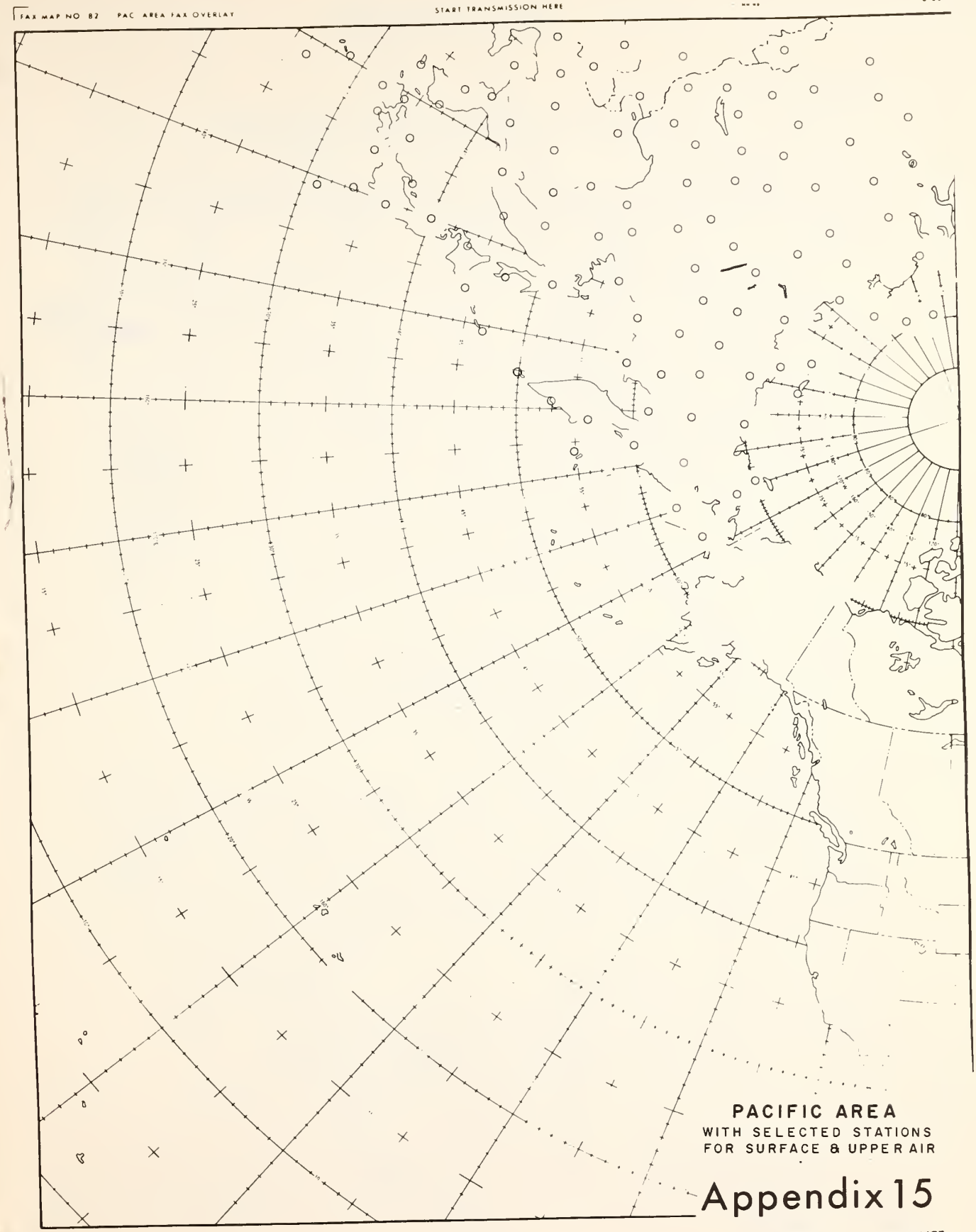
Appendix 14



ATLANTIC AREA
WITH SELECTED STATIONS
FOR SURFACE & UPPER AIR

Appendix 15

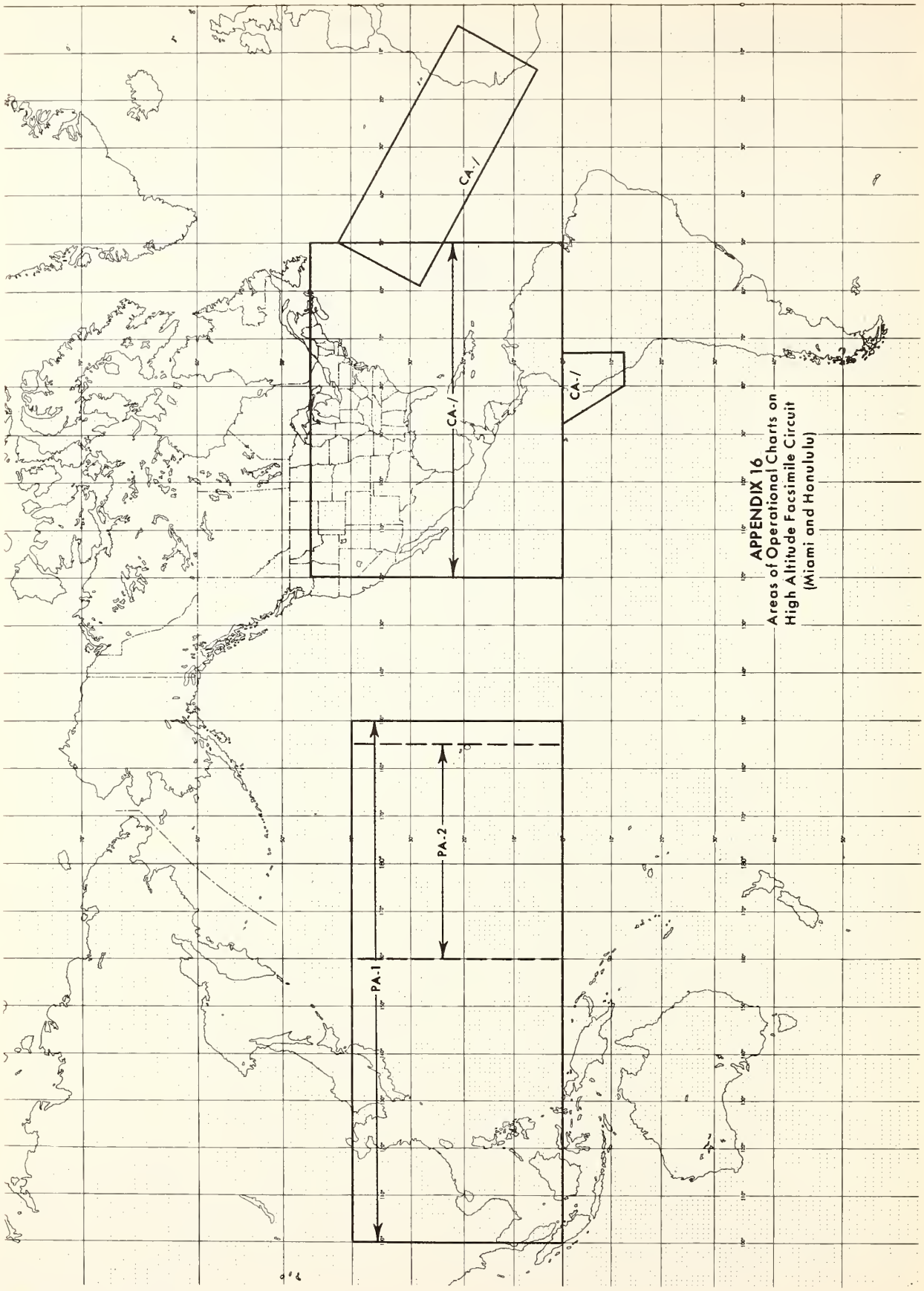
FAX MAP NO 82 PAC AREA FAX OVERLAY START TRANSMISSION HERE 6 65



PACIFIC AREA
WITH SELECTED STATIONS
FOR SURFACE & UPPER AIR

Appendix 15

WBFH NO. 1 ISSUANCE
67-1 10-1-67



APPENDIX 16
Areas of Operational Charts on High Altitude Facsimile Circuit (Miami and Honolulu)

Appendix 17

SURFACE AND THICKNESS PROGNOSIS

Figure 1 in this appendix indicates the flow of prognostic products along with the principal charts and tools used in the preparation of the prognoses.

F o r e c a s t P r o c e d u r e s

SURFACE PROGNOSES

1. TOOLS AVAILABLE:

   a. Initial surface, 500 mb, 1000-500 mb thickness, and 500 mb analyses.

   b. 3 and 12 hourly surface and 12 hourly 500 mb tendencies.

   c. Past history.

   d. NWP 500 mb, 500 mb vorticity, and advection of 500 mb vorticity by 500 mb pattern.

   e. The empirical and physical atmospheric relationships listed in the upper left-hand side of figure 1. These provide the forecaster with a means of producing a surface prognosis internally consistent with a given 500 mb prognosis.

Additional information useful to the surface prognosis is provided by the climatology of mountains, normal storm tracks, and cyclogenesis. Objective computations devised by J. J. George (1), Ostby-Veigas (2), and Riehl-Haggard (3) are used more or less routinely. Reference (1) contains a comprehensive system of objective computations. Of these, NMC has found the one dealing with the deepening of east coast cyclones to be most useful. The Ostby-Veigas computation also provides forecasts of east coast cyclogenesis.

2. PREPARATION:

   a. A thorough study of existing relationships between sea level, 500 mb, 1000-500 mb thickness, and 500 mb vorticity is made. Points to be especially noted are:

a) Empirical Relationships

1. Correlation – H_5, T_5, Z_5.
2. Troughs & Ridges vertical above H_5.
3. Average slope in Baroclinic regions – 5° Lat.
4. Atmosphere in approximate geostrophic balance.
5. Atmospheric models.
   a. Cyclone model (3 dimensional).
   b. Jet stream models.

b) Physical Relationships.

1. Dines compensation
2. Eq. continuity
3. Hydrostatic eq.
4. Geostrophic & Thermal wind equations.
5. Sutcliffe eq.

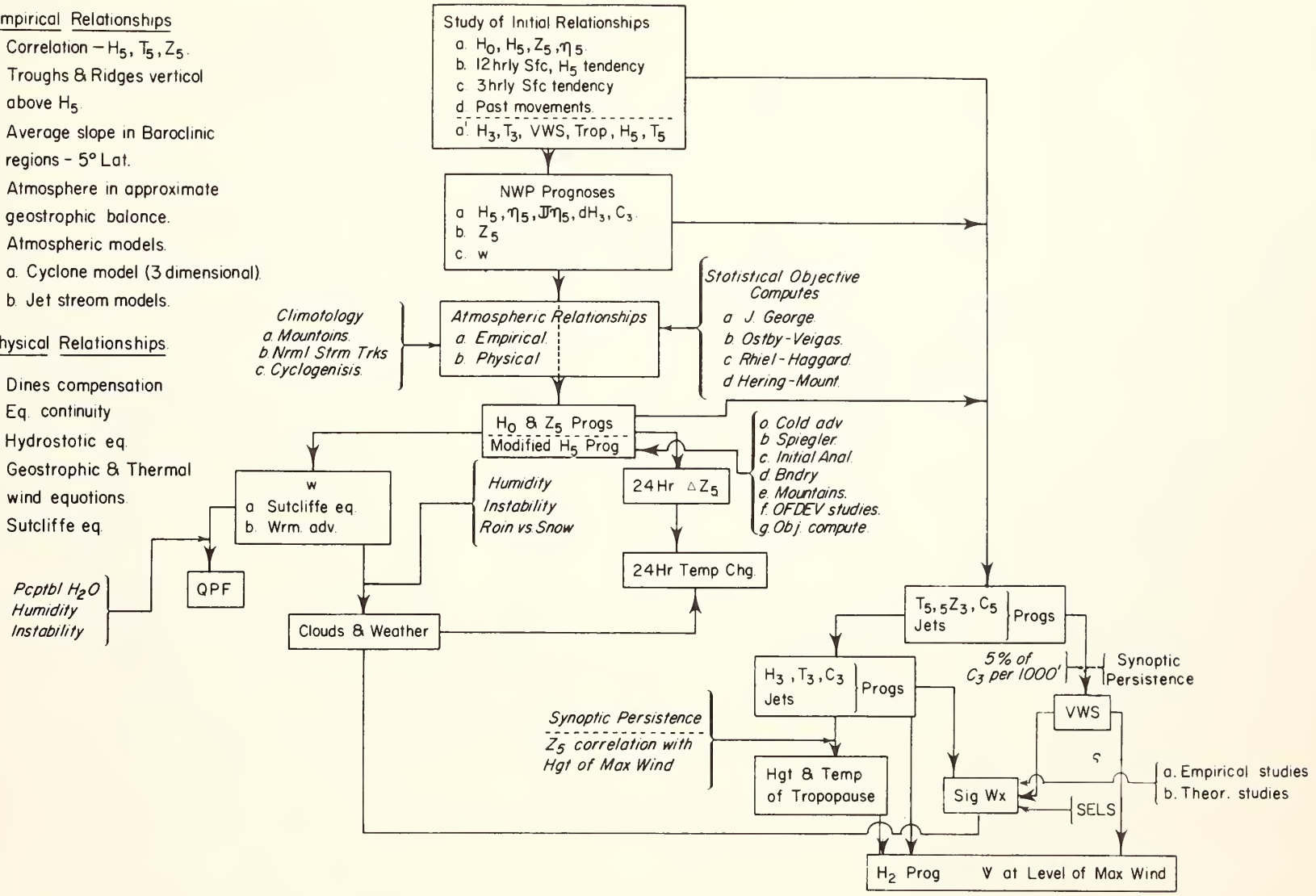


Figure 1

Flow Diagram of NAWAC Prognostic Products

1). Barotropic or equivalent barotropic regions.

2). The slopes of baroclinic cyclones and anticyclones. Anomalous situations and reasons for same should be noted.

3). The major baroclinic zones as indicated by the 1000-500 mb thickness.

4). An analysis of 3 and 12 hourly surface tendencies along with 12 hourly 500 mb and 1000-500 mb thickness tendencies to determine the extent to which the surface tendency is a result of either the 500 mb or 1000-500 thickness change or both. This information is useful in diagnosing qualitatively, whether changes predicted in the NWP 500 mb prognosis are currently in progress or not.

5). A qualitative analysis of the clouds and precipitation with emphasis on the vertical motion as determined by the Sutcliffe equation.

6). An analysis of cyclogenesis or development in terms of the Sutcliffe equation.

In short, step (a) consists of explaining in physical terms as completely as possible what has and is happening at the initial time.

b. The prognosis in the barotropic or equivalent barotropic regions is prepared next. This includes the movements of warm highs and cold lows. This step is easily and quickly accomplished by displacing the systems with the velocity of their 500 mb counterparts. Changes in shape and intensity can be taken into account quantitatively.

c. The baroclinic systems are displaced with the velocity indicated by the NWP barotropic prognosis. The initial and forecast vorticity charts provide the simplest means of obtaining the desired velocity. The associated surface features are displaced with this velocity. This amounts to maintaining existing slopes through the forecast period.

The position of major frontal zones are forecast making use of--

1). Forecast positions of the baroclinic systems.

2). Initial relationships between fronts and 500 mb and the NWP 500 mb forecast.

Since the 500 mb vorticity gradients give a good indication of the horizontal position of the 500 mb jet, they, along with the usual relationship of major frontal zones to the jet, can be used as a guide to forecast frontal positions.

d. Isobars in the baroclinic regions are constructed next, keeping in mind at all times what the geostrophic vorticity of these isobars will mean in terms of the weather. This amounts to predicting an accurate thickness pattern assuming the NWP prognosis will be correct.

The 1000-500 mb thickness forecast is on occasion made for the complete forecast area and then subtracted from the 500 mb prognosis. However, the usual practice is to make quantitative estimates of 1000-500 mb thickness at discrete points. Discrete points include forecast positions of low centers, high centers, ridge and trough lines, cols, etc. This will give quantitative forecasts of changes in pressure for significant features of the sea-level pattern.

REFERENCES:

1. George, J. J., et al., "Forecasting Relationships Between Upper Level Flow and Surface Meteorological Processes," Geophysical Research Papers, No. 23, Air Force Cambridge Research Center, Cambridge, Mass. August 1953.

2. Ostby, F. P., and Veigas, K. W., "A Moving Co-Ordinate Prediction Model Applied to East Coast Cyclones," Scientific Report No. 1 Contract No. AF 19 (604)-5207, The Travelers Weather Research Center, November 1960.

3. Riehl, H., Haggard, W. H., and Sanborn, R. W., "On the Prediction of 24-hr. Hurricane Motion," Journal of Meteorology, Volume 13, 1956, pp. 415-420.

THICKNESS PROGNOSES

1. TOOLS AVAILABLE:

a. The NWP 500 mb prognosis. This follows from the observed fact that troughs are cold and ridges warm.

b. The advection of 1000-500 mb thickness with a fraction of the initial sea-level geostrophic wind. Fractions used are those that have been derived empirically by L. A. Hughes (4).

c. The thickness model illustrated in appendix 4.

2. PREPARATION

The procedure outlined in Surface Prognoses under Preparation, step (a) is also followed here.

Consistency Check

The sea-level forecast is then converted to a 1000 mb chart and subtracted from the NWP 500 mb forecast to obtain 1000-500 mb thickness.

At this point, consistency checks are made to determine if the 1000-500 mb thickness forecast is in line with the appropriate basic physical principles. If not, and the NWP 500 mb forecast is believed correct, the sea-level prognosis is changed to bring about consistency. If the NWP 500 mb forecast is believed in error, the 1000-500 mb thickness forecast is altered and added to 1000 mb to obtain a modified NWP 500 mb forecast. To be most successful, the modifications should be in accordance with points made in chapter 1 concerning typical barotropic errors.

It should be emphasized at this point that the most useful consistency check concerns the 1000-500 mb thickness and 500 mb patterns. These patterns in all their major features should be similar. The out-of phaseness between 1000-500 mb thickness and 500 mb troughs and ridges should not exceed 5° of latitude such that the 1000-500 mb thickness troughs and ridges lag the corresponding 500 mb troughs and ridges.

REFERENCES:

1. Hughes, L. A., "On the Determination of 500 mb Height Tendencies," Bulletin of the American Meteorological Society, Volume 38, No. 4, April 1957.

Appendix 18

MODIFICATION OF UPPER AIR PROGS

Modification of errors arising in the barotropic forecast are listed in order of importance:

1. Those associated with low level cyclongenesis, or more generally, baroclinic processes.

2. Those due to initial analysis errors.

3. Those due to mountains.

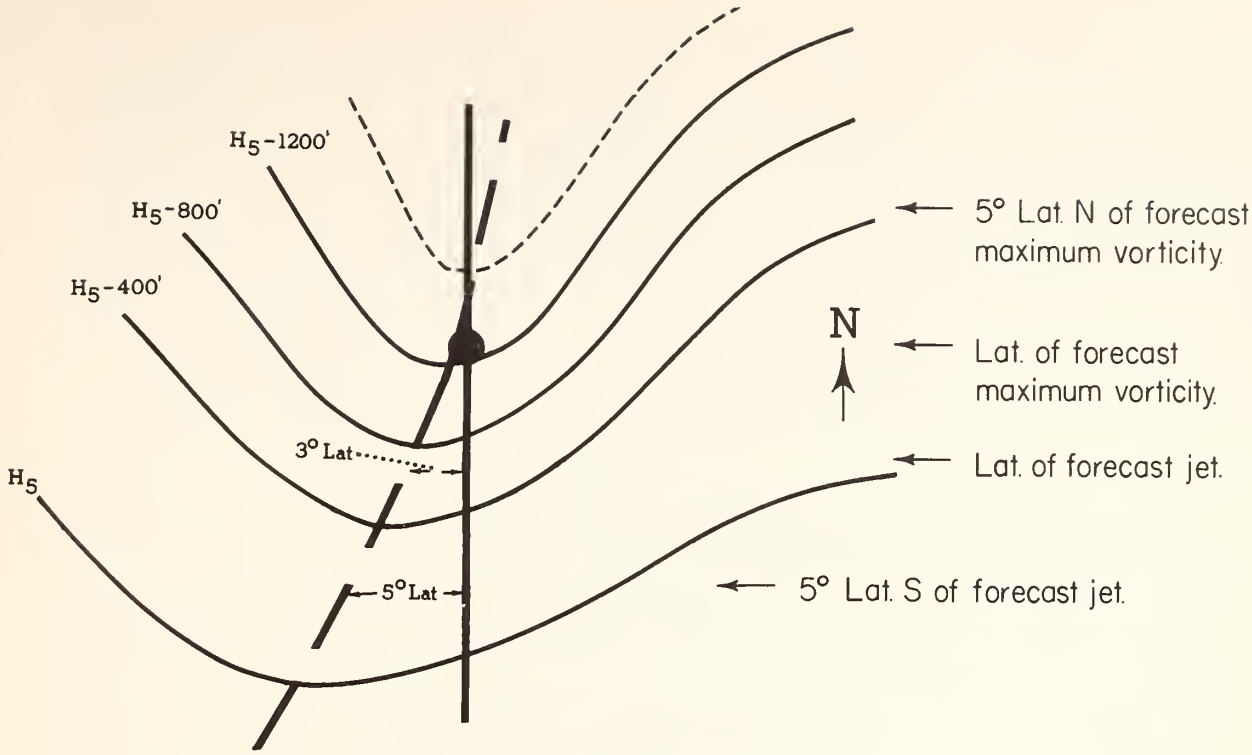
4. Diabatic heating errors and,

5. Boundary errors.

Experience at NMC indicates that all of the above, except 1 are difficult to handle successfully. There are two reasons for this. First, errors of type 1 are usually of much greater magnitude, and second, the barotropic prediction itself is of considerable assistance in determing where the errors of type 1 will occur. (The latter statement is just another way of stating the fact that the baroclinic short waves operate in the framework of a barotropic atmosphere.) Therefore, for now, the discussion of barotropic errors will be limited to those of class 1.

Studies in NMC have indicated that typical errors in the barotropic forecasts of trough positions over North America and adjacent oceans, are as indicated in figure 1. The 500 mb contours are a characteristics forecast pattern. The forecast trough position is shown as a heavy dashed line, a and the verifying trough as a heavy solid line. These studies have indicated that the forecast latitude of the jet stream through the trough, and the vorticity maximum in the trough, are by and large fairly accurate. At least there is no tendency for the forecast to be, on the average, either too far north or south. However, these studies have indicated that the most accurate forecast of trough displacement occurs at the latitude of the forecast vorticity maximum. At the same time, the trough forecast south of the vorticity maximum is slow, the degree of slowness increasing southward, and the trough forecast north of the vorticity maximum slightly fast. Actual values needed to correct the bias in the forecast are indicated in the figure. It will be noticed that corrections to the forecast trough result in a counterclockwise rotation of the axis of the trough using the position of the vorticity maximum as the point of rotation.

Appendix 18



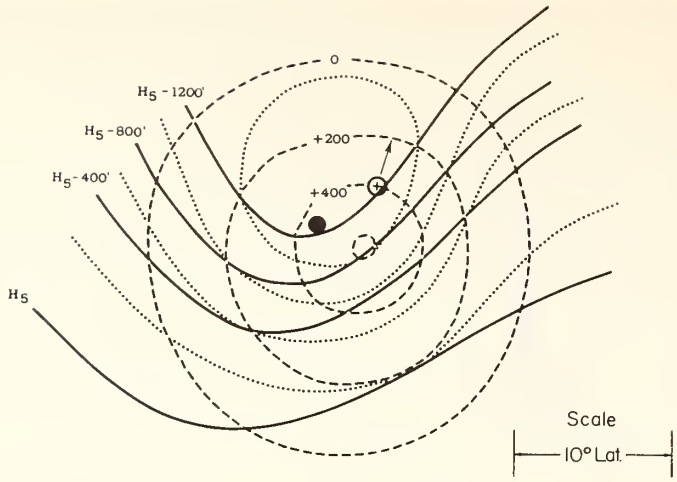
Characteristic Barotropic errors in Trough Displacement.

● Position of forecast maximum vorticity.

Figure 1

A recent study by Spiegler (1) gives some interesting and useful facts concerning barotropic errors in 24-hour forecasts for 30 cases in which sea level cyclones deepened 20 mb or more in 24 hours. The area of the origin of these cases extended from 100° W to 60° W and S of 50° N. The most significant fact is that the composite height change charts for the 30 cases indicate that the barotropic forecasts predicted the area of maximum height decrease in approximately the right location. Spiegler also found that the center of the composite observed 24-hour 500 mb height falls lay 5° of latitude to the rear of the surface cyclone position at the end of the 24-hour period. To the "rear" is defined as opposite to the direction of motion of the cyclone. These two facts, then, show that the barotropic forecast is not only useful in determining the position of the surface cyclone but also, in cases of cyclogenesis, the position of the 500 mb errors in the forecast due to the cyclogenesis.

What do Spiegler's results imply in so far as errors in trough movement are concerned? Are they related to the typical errors shown in figure 1. In figure 2, we have applied the composite barotropic error of Spiegler's



Characteristic Borotrapic errors associated with Cyclogenesis

—— 24 haur borotrapic forecast

● 24 haur barotrapic farecast vorticity maximum

⊕ Forecast position af low-level cyclagenesis based on barotropic forecast (Arrow indicates direction of movement)

--- Error in 24 haur barotropic farecast.

····· Observed 500mb pattern.

Figure 2

30 cases to the 500 mb trough of figure 1. The center of maximum error has been placed 3° to 4° of latitude to the rear of the surface cyclone in accordance with (2). The surface cyclone is placed about 5° downstream from the forecast 500 mb vorticity maximum in accordance with the normal slope between surface and 500 mb systems. An examination of figure 1 will reveal that the composite quantitative errors bring about corrections to the trough movement in the same sense as illustrated in figure 2, a counterclockwise rotation of the trough about the position of the forecast vorticity maximum.

In addition, the quantitative errors reveal another very important correction to the barotropic forecast. This is a significant decrease in westerlies (increase in amplitude) of the trough north of the latitude of the forecast vorticity maximum, and a significant increase in westerlies (decrease in amplitude) south of the latitude of the forecast vorticity maximum.

The typical errors above will naturally not work out to the forecasters advantage if applied in all cases of trough movement and development. But in cases when modifications are applied to the barotropic forecast, the forecaster will be most successful if they result in modifications in line with the above.

Thus far, we have been considering only positive barotropic errors (forecast too high) and that these positive errors are intimately associated with areas of cold air advection as indicated, for instance, by the advection of the 1000 to 500 mb thickness by the sea-level geostrophic wind. Experience shows that large positive errors can occur in the barotropic forecasts without appreciable sea-level cyclogenesis. At the same time, appreciable cyclogenesis can occur without large positive errors, especially over oceanic regions. The point to be made is that experience shows there is a better correlation between positive errors and strong cold advection than positive errors and sea-level cyclogenesis.

We now come to the main point of this discussion on typical barotropic errors--what modifications are introduced to the second approximation to the vertical motion by these errors?

It is clearly seen that the modifications amount to a counterclockwise rotation of the vertical motion field obtained in the second approximation. The area of upward motion is extended westward north of the latitude of the 500 mb vorticity maximum, and the area of sinking motion extended eastward in the area of cold advection south of the latitude of the 500 mb vorticity maxima.

MODIFICATIONS INTRODUCED BY CONSIDERATION OF FRICTION AND STABILITY

Estimates of the upward vertical velocity induced by surface friction under conditions of moderate cyclonic circulation ($\zeta \approx 10^{-4}$ sec.$^{-1}$) amount to 1 to 2 cm/sec. These values are certainly of importance in the development of clouds and precipitation in areas where 1. the large-scale dynamical vertical motion is relatively small, and 2. the air is relatively unstable. Consideration of the frictional vertical velocity along with conditions 1. and 2. results in upward motion and hence forecasts of clouds and precipitation farther from the center in the NW and SW quadrants in the developing and fully occluded stages.

SUMMARY:

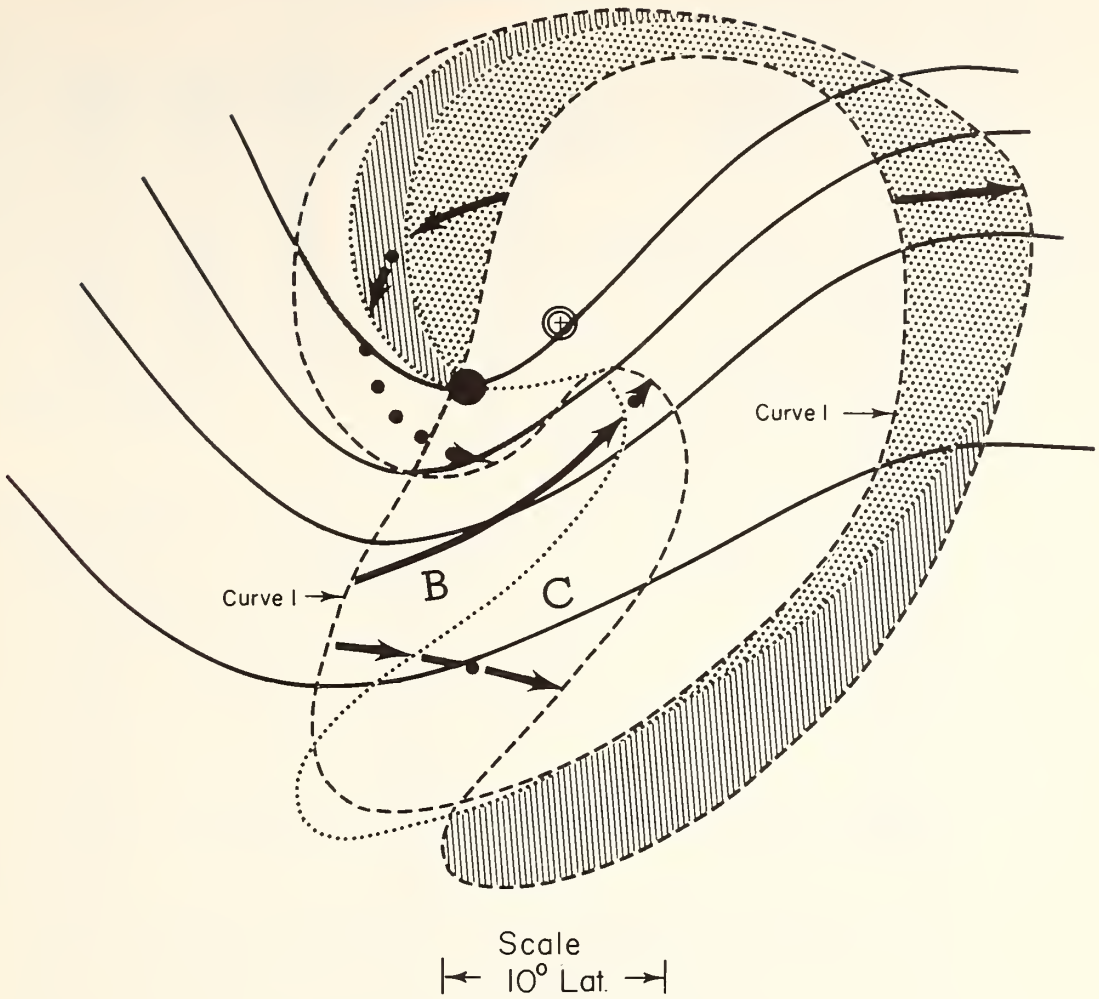
Typical modifications to the equivalent barotropic vertical motion introduced by considerations of the various approximations and errors in cases of low level cyclogenesis are illustrated schematically in appendix 19. The reader will note that in essence, the overeffect is for a rotation of the equivalent barotropic field of vertical motion by the low level circulation. The largest distortion occurs in the center of the baroclinic zone as indicated by the 1000-500 mb thickness field. Naturally there are many variations to what is pictured in appendix 19. Assuming for the moment a high correlation between rising motion determined from the theory and experience in barotropic model and its modifications and weather--a rather large assumption--the forecaster is still faced with the formidable job of predicting the surface vorticity patterns. However, experience in NMC has shown that when clouds and precipitation are to be forecast in areas other than might be diagnosed

on the basis of the equivalent barotropic vertical motion alone, these forecasts are most successful if made in qualitative agreement with appendix 19. In short, these forecasts should be in line with the barotropic forecast and realistic physical and empirical atmospheric models.

REFERENCES:

1. Spiegler, D. B., "An Analysis of Barotropic Forecast Errors in Cases of Rapid Sea Level Cyclogenesis," Monthly Weather Review, Volume 88, No. 8, August 1960, pp. 263-268.

Appendix 19



Schematic representation of modifications to equivalent-barotropic vertical motion introduced by:

B. Normal slope between developing cyclone and 500mb. pattern,
C. Typical barotropic errors, and
D. Friction and instability.

—— Typical Barotropic 500mb. forecast.

Area of equivalent barotropic rising motion enclosed by Curve I.

Area of rising motion added by B = ⁙
C = ||||||
D =

Area of rising motion subtracted by B labeled B.
Area of rising motion subtracted by C labeled C.

● = position of forecast 500mb. vorticity maximum.

⊕ = position of forecast surface cyclone.

Appendix 19

QUANTITATIVE PRECIPITATION FORECAST (QPF)

Forecast Procedures

1. TOOLS AVAILABLE:

   a. Vertical motion.

      1). Empirical (warm advection).

      2). Sutcliffe equation.

   b. Precipitable water.

   c. Humidity.

   d. Stability.

2. PREPARATION:

   a. Computation of vertical velocities at beginning and end of forecast period.

      The principal indicator of vertical motion is the advection of the 1000-500 mb thickness field by the 1000 mb geostrophic wind. The sign of the vertical motion is determined by the sense of this advection and the magnitude by the areas of the quadrilaterals formed by the intersections of the isopleths of 1000 mb and 1000-500 mb thickness.

      The areas of the quadrilaterals, converted to what are called warm advection units (W.A.U.), have been empirically correlated by the QPF section to the precipitable water between 1000 and 500 mb and the 6-hourly precipitation amount. The scale used in measuring areas and the correlations are shown in figure 1.

      The computation of the initial indicated warm air advection is made from a 3-hour 1000 mb prognosis and the 12-hour barotropic prognosis. Specifically, for the QPF verifying at 12 GMT this would be a 3-hour 1000 mb prognosis from 09 GMT and the 12-hour barotropic prognosis from 0000 GMT. The computation at the end of the 24-hour period is made from the appropriate National

W.A.U.	AREA OF QUADRILATERAL LATITUDE *				
	30°	35°	40°	45°	50°
0.5	120	87	61	47	36
1	62	44	31	24	18
1.5	31	22	16	12	9.5
2	16	11	7.8	5.9	4.5
3	11	7.4	5.2	3.9	3.0
4	8.0	5.5	3.8	2.9	2.2
5	6.4	4.4	3.1	2.3	1.7
6	5.4	3.7	2.6	2.0	1.5
7	4.6	3.2	2.2	1.7	1.3

*200ft. contours

PRECIPITABLE WATER	6HR PRECIP AMT PER W.A.U.
.25 INCH	.05
.50	.09
.75	.13
1.00	.18
1.25	.24
1.50	.31
1.75	.39
2.00	.50

MEASURING SCALE FOR QUADRILATERALS. UNITS 1° OF LAT. AT 40° N ON POLAR STEREOGRAPHIC PROJECTION. TRUE AT 60°. SCALE 1:20,000,000

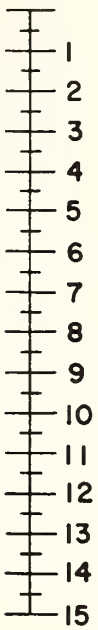


Figure 1

Weather Analysis Center, 1000 mb and 1000-500 mb thickness prognoses. The computations are made at discrete points, and then isopleths of W.A.U. are drawn.

b. Evaluation of duration and intensity of W.A.U. for 24-hour period.

In cases where there is continuity of movement of the warm advection areas, duration and intensity is determined by graphical linear interpolations. The simplest case is a warm advection area that remains stationary and of the same intensity for 24 hours. In other instances, intermediate patterns of warm advection are drawn in order to determine graphically the duration and intensity. If a new warm advection area is forecast, a subjective evaluation of when it first appears during the period must be made.

c. Forecast of precipitable water.

This step is primarily subjective. Heavy reliance is placed on the initial distribution of precipitable water, an approximation for which can be obtained in areas of precipitation by noting the saturation value of the initial 1000-500 mb thickness obtained in step (a) in these areas. Continuity is used. When appropriate, advection of the precipitable water by the 850 mb wind is used. However, advecting a quantity that is integrated through a layer 500 mb thick, can become a highly complicated operation.

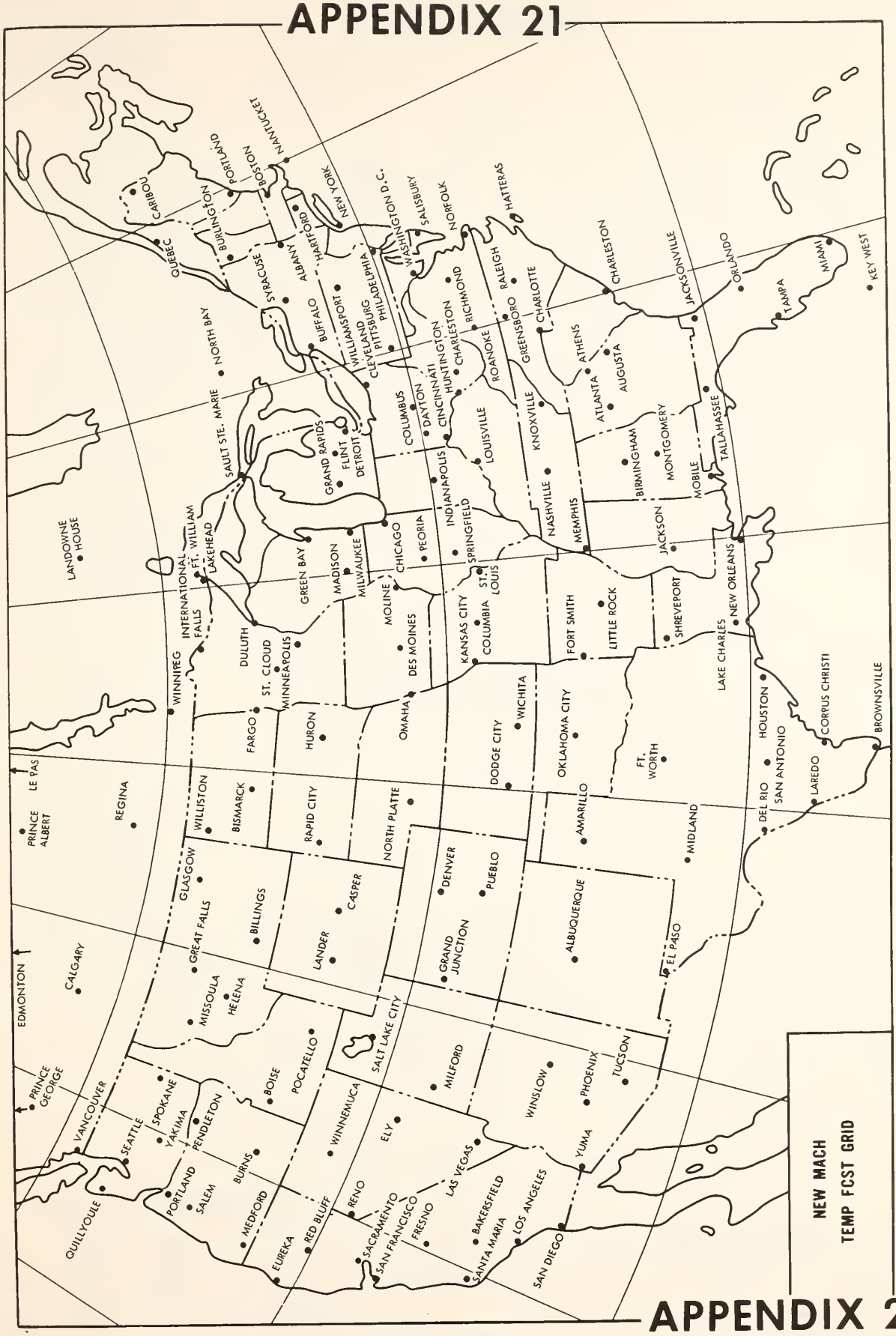
d. Computation of precipitation amounts.

In cases when the area of warm advection is associated with precipitation at the initial time, this is accomplished simply by using the results of steps (b) and (c) and entering the lower left hand table of figure 1. One of the most difficult problems which is well-known to all forecasters is when precipitation will begin in a previously dry system. To help with this problem, a relative humidity chart of the layer between 1000 and 500 mb is used. The relative humidity is obtained by dividing the actual precipitable water by that which could be held by a saturated standard atmosphere corresponding to the observed 1000-500 mb thickness. Subjective estimates are made concerning the onset of precipitation using the relative humidity chart and the indicated warm advection. A rough objective guide is, that one W.A.U. will increase the relative humidity 15% in 12 hours.

SUMMERTIME QUANTITATIVE PRECIPITATION FORECASTING

The physical logic of the system just described, breaks down when applied to summertime precipitation. At the same time, the system is useful. It is useful because the meso-scale precipitation patterns of summer usually occur in areas where the macro-scale vertical motion is favorable. Not much further can be said about summer quantitative precipitation forecasting, except to note that stability and moisture are considered more closely, and synoptic experience plays a greater role in the success of the forecast than is the case in winter.

APPENDIX 21



APPENDIX 21

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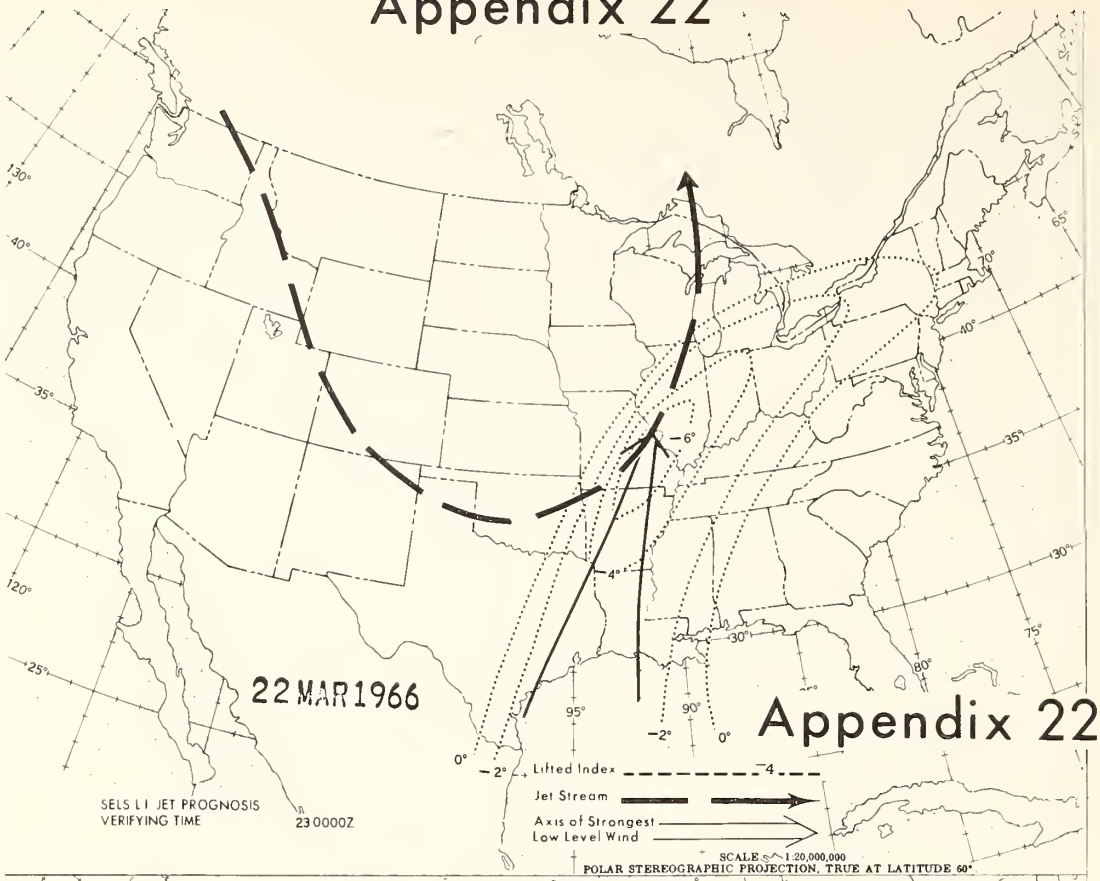
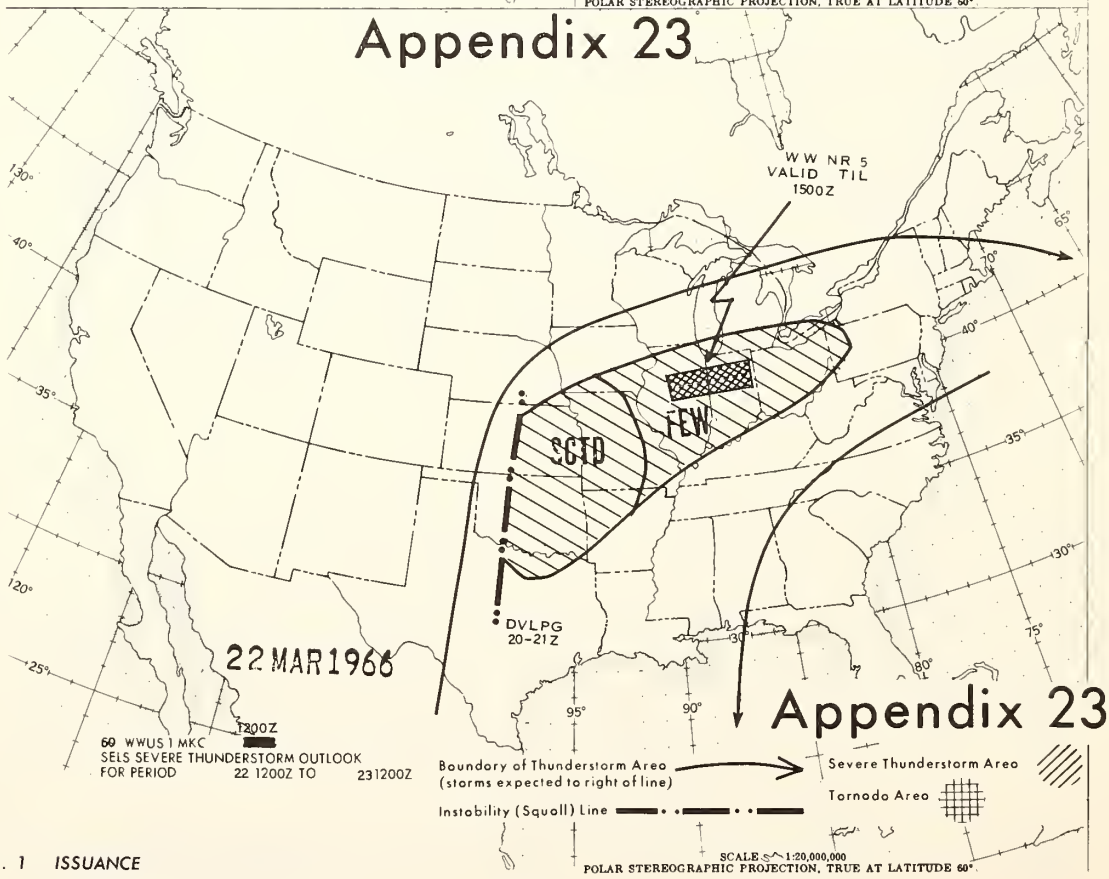
Appendix 22



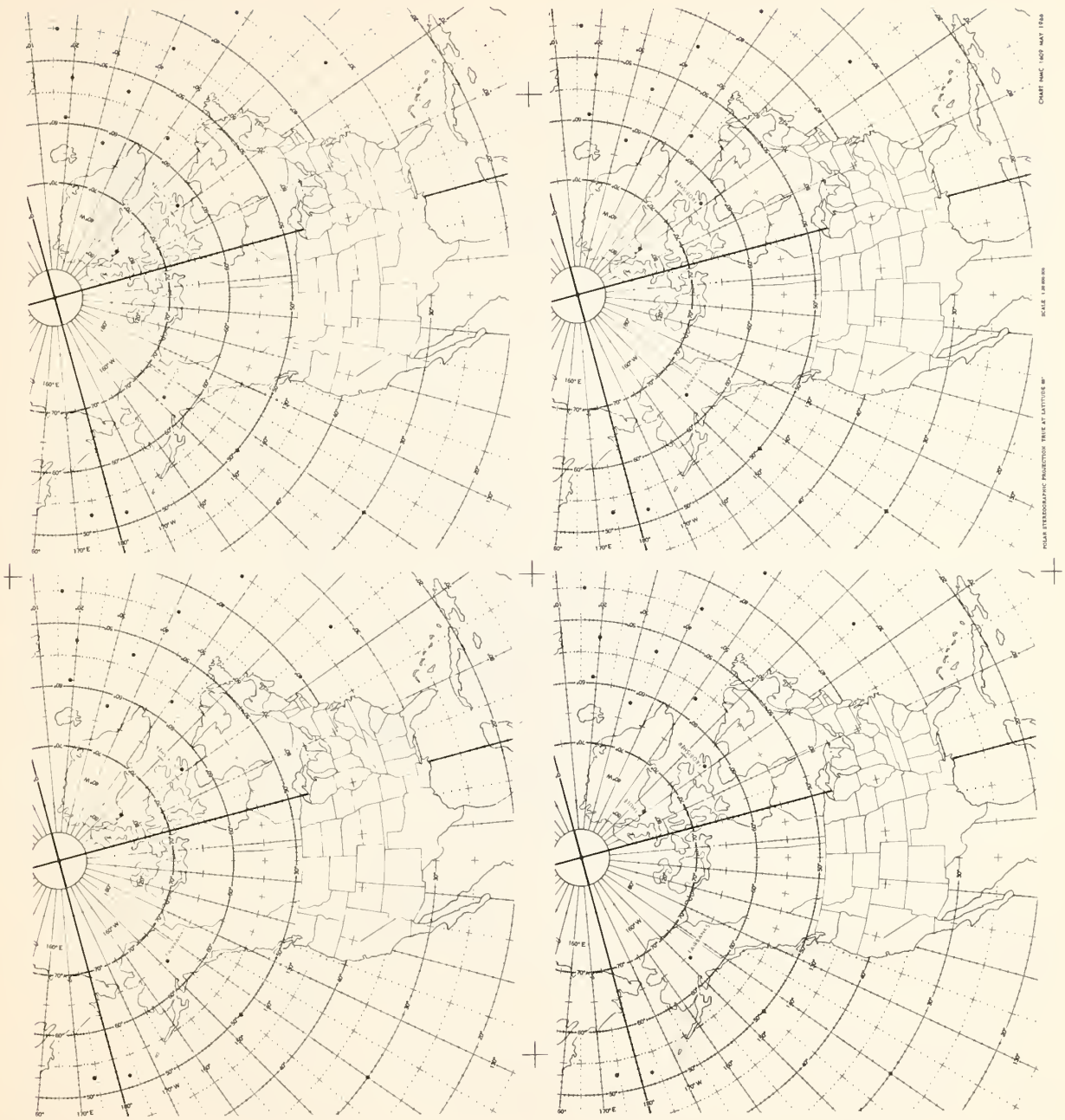
Appendix 22

Appendix 23



Appendix 23

Appendix 24



APPENDIX 25

Areas of Operational
Charts on High Altitude
Facsimile Circuit

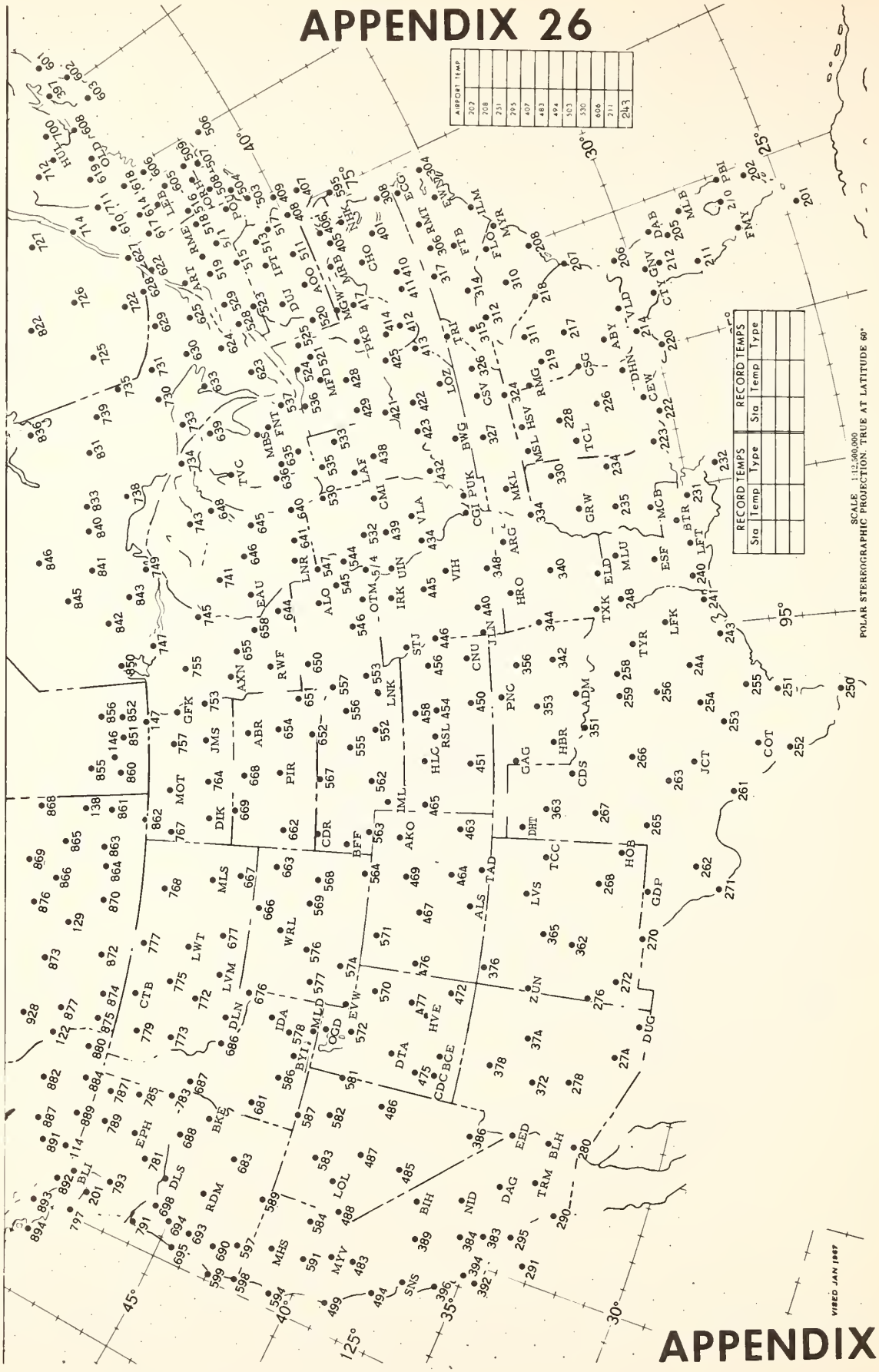
REVISED OCT. 1967

APPENDIX 25A

Areas of Operational
Charts on High Altitude
Facsimile Circuit

REVISED OCT. 1967

APPENDIX 26



APPENDIX 26

Appendix 27

PRESENTATION OF "ON-TIME" PRECIPITATION FORECASTS

The following method of presenting "on-time" precipitation forecasts is used on all NMC short-range (i.e., 12 to 48 hour) surface prognoses.

1. A solid line is used to define areas within which the predominant precipitation is forecast to result from any type of large-scale vertical motion (e.g., overrunning) or from continuous locally induced vertical motions (e.g., "upslope" flow or Gulf drizzle). These areas are used most often in winter precipitation situations. When equal to or greater than 50% area coverage is forecast, these areas are stippled on the facsimile charts. When less than 50% area coverage of precipitation is forecast, these areas are left blank on the facsimile charts, except for the precipitation symbol. The forecast precipitation type will be indicated by the following symbols:

Drizzle

1. Continuous Heavy ,', 2. Continuous Moderate ,',

3. Continuous Light , , 4. Intermittent ,

Rain

1. Continuous Heavy .'. 2. Continuous Moderate .'.

3. Continuous Light . . 4. Intermittent

Snow

1. Continuous Heavy *'* 2. Continuous Moderate *'*

3. Continuous Light * * 4. Intermittent *

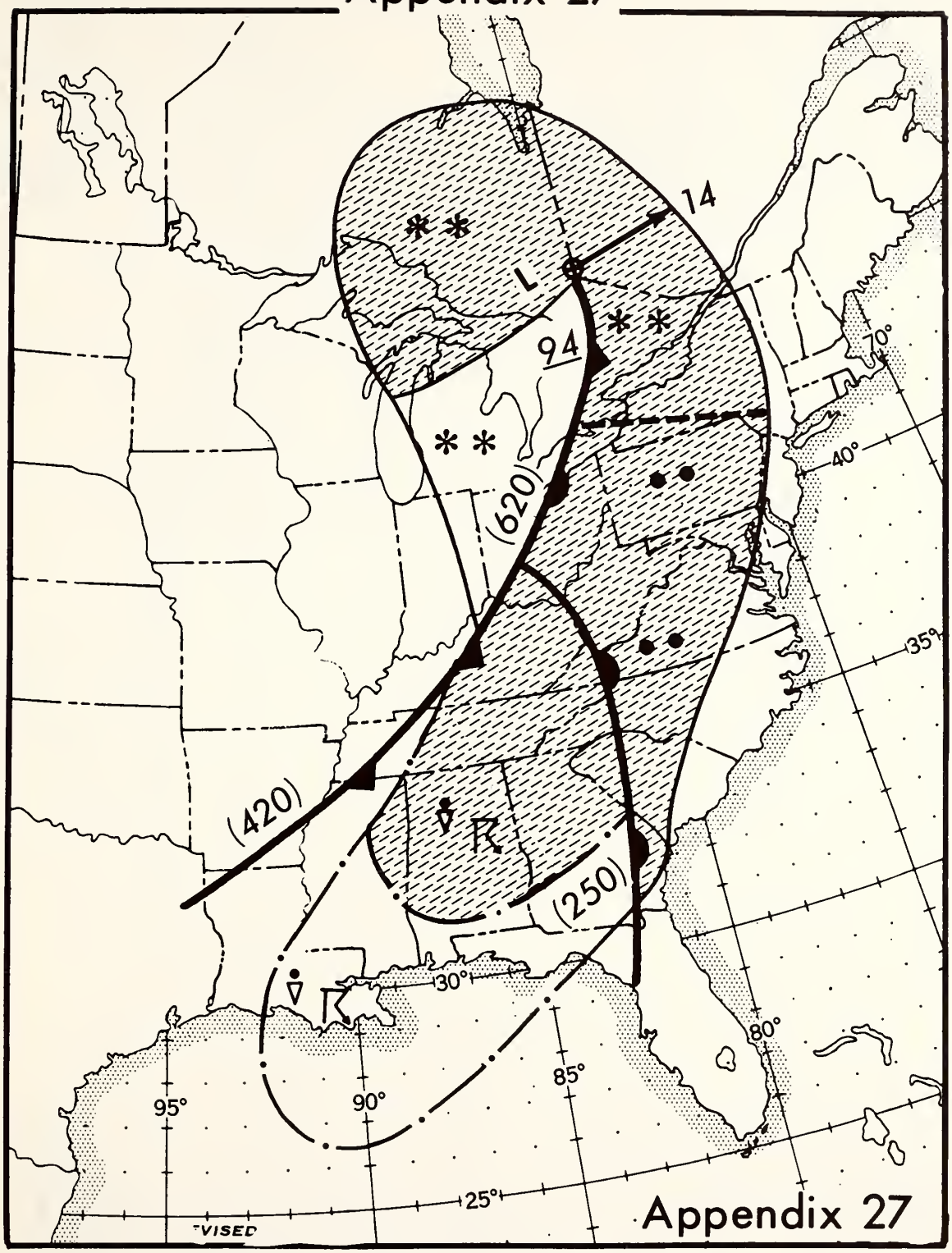
Normally the symbol for continuous light precipitation is used. Occasionally, the symbols for moderate and heavy intensities may be used to conform with large amounts shown in the quantitative precipitation forecast.

2. A "dashed-dot" line is used to define areas within which predominant precipitation is forecast to be of convective or unstable shower type due largely to local, small-scale vertical motions. These areas are used most often in warmer season precipitation situations.

   Stippling is also used in presenting the area coverage of showers. That is, no stippling below 50% coverage and stippling for 50% or greater coverage. The type of shower activity expected is indicated by standard shower and/or thunderstorm symbols. No indication of intensity is given.

3. The solid-line divisions within precipitation or shower areas indicate changes in area coverage, i.e., from less than 50% to 50% or more, rather than change in type or intensity. The division of frozen and non-frozen precipitation within these areas is delineated by a dashed line and the appropriate change in symbol on either side of this line.

Appendix 27



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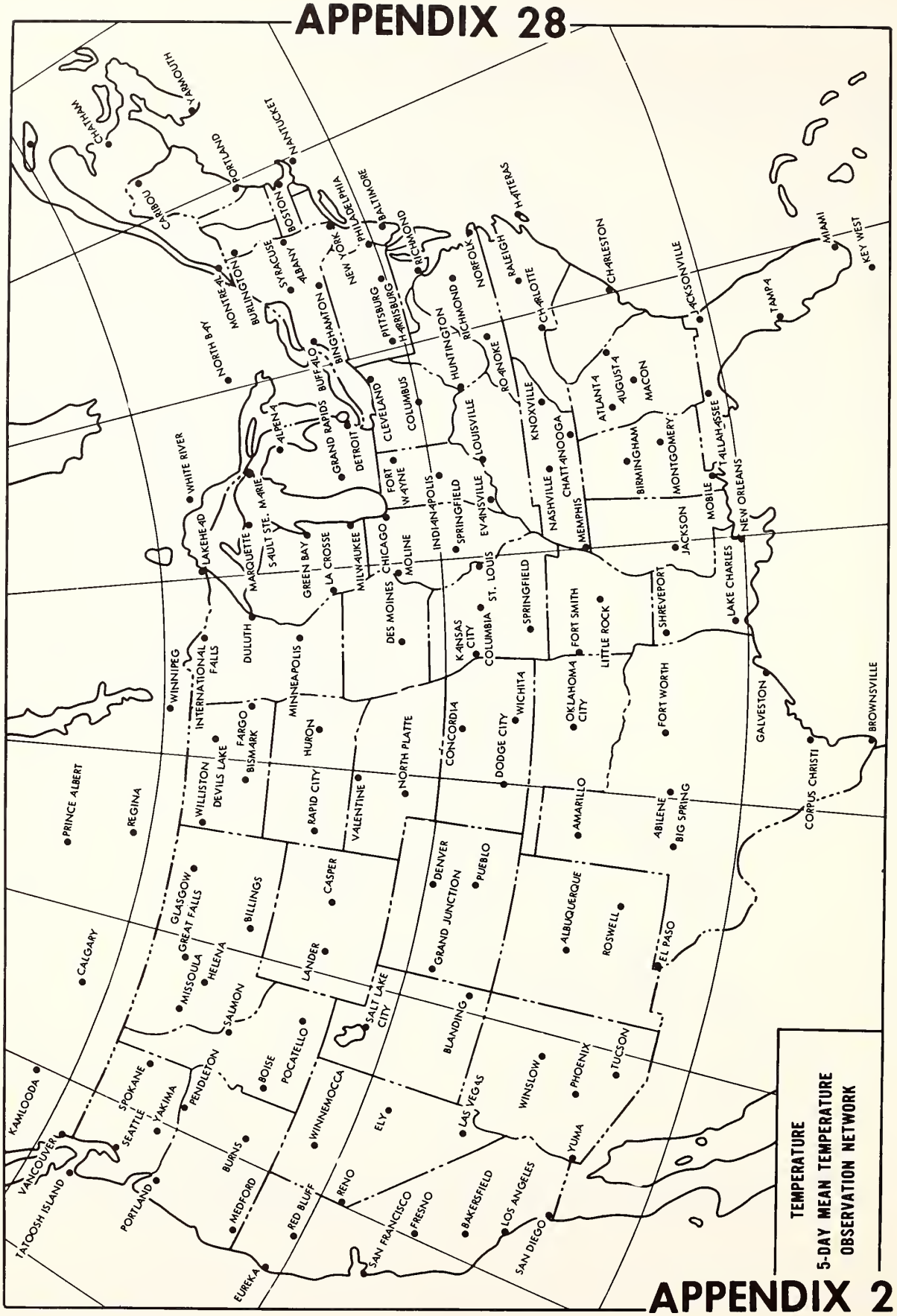

APPENDIX 28

APPENDIX 29

PRECIPITATION
5-DAY PRECIPITATION AMOUNT
OBSERVATION NETWORK

APPENDIX 29

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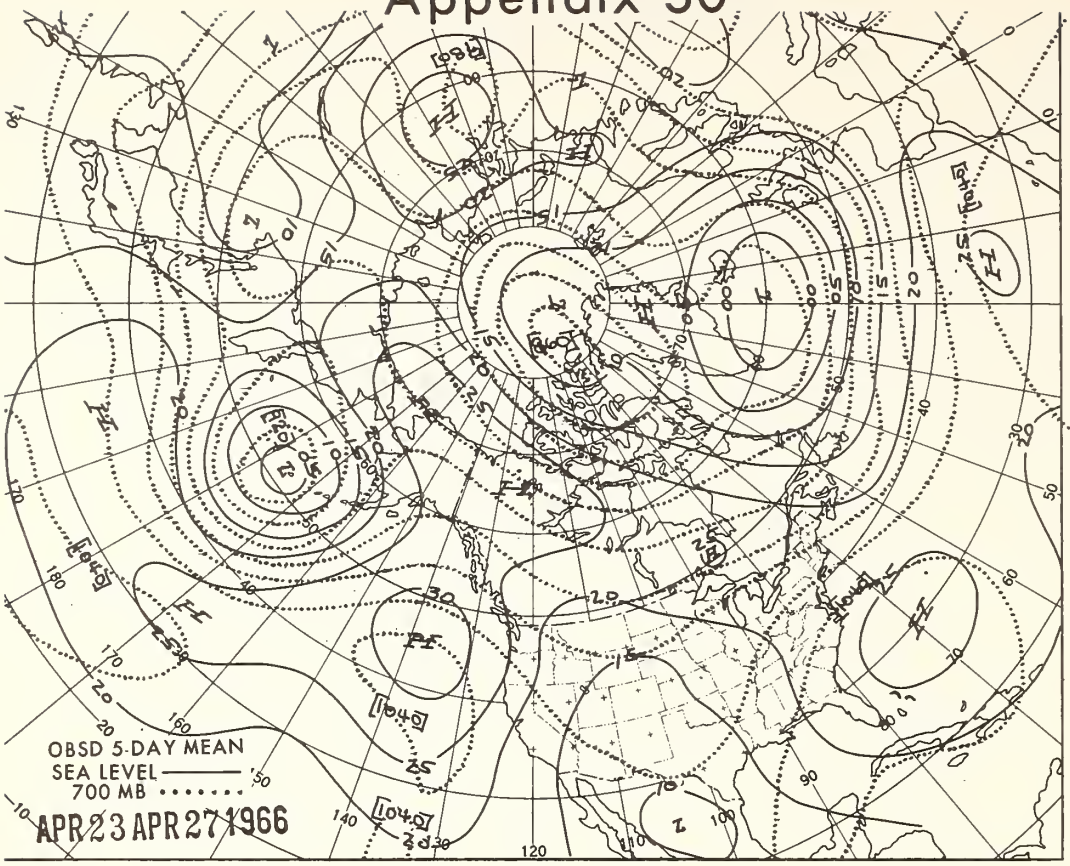
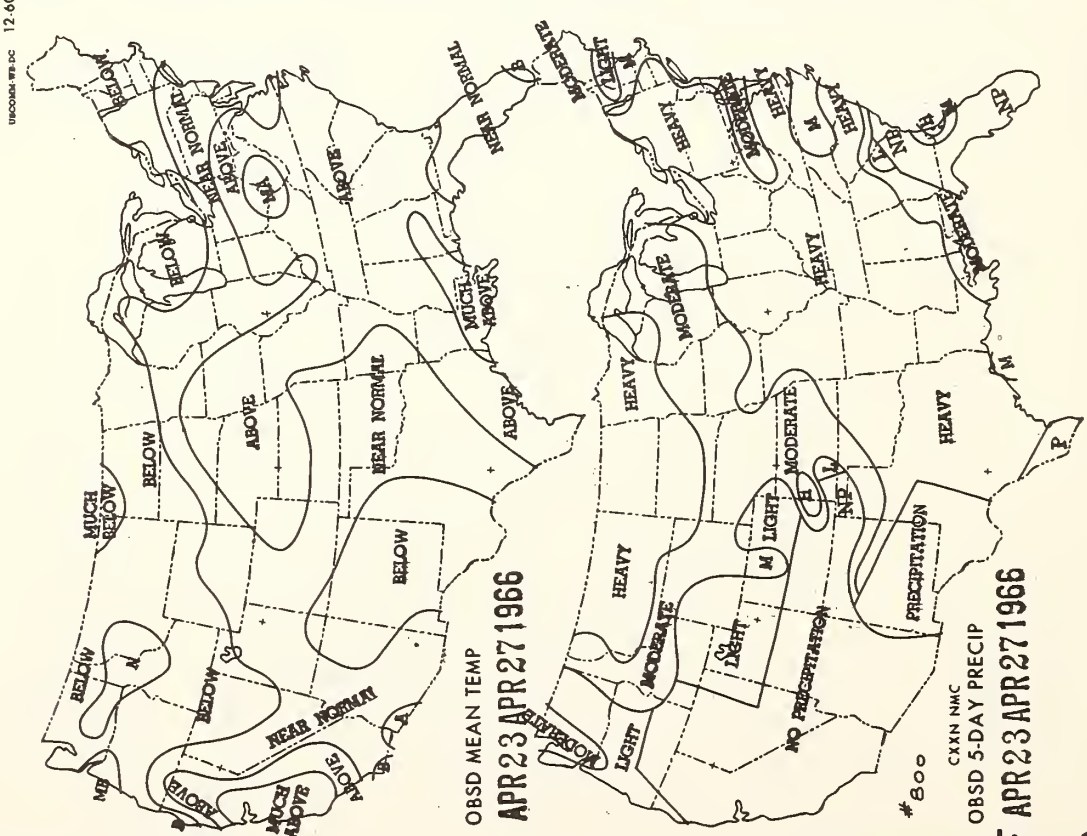
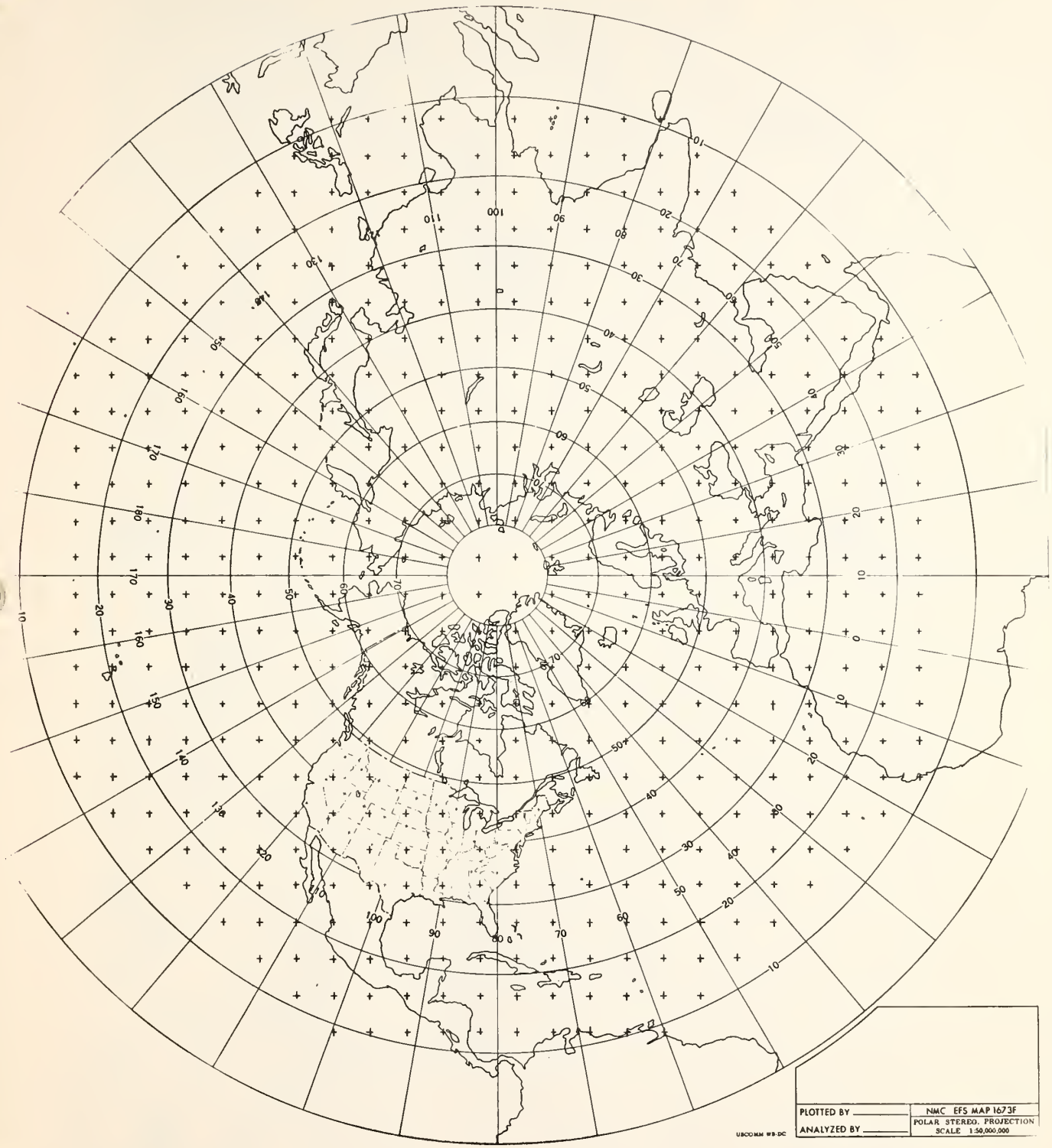
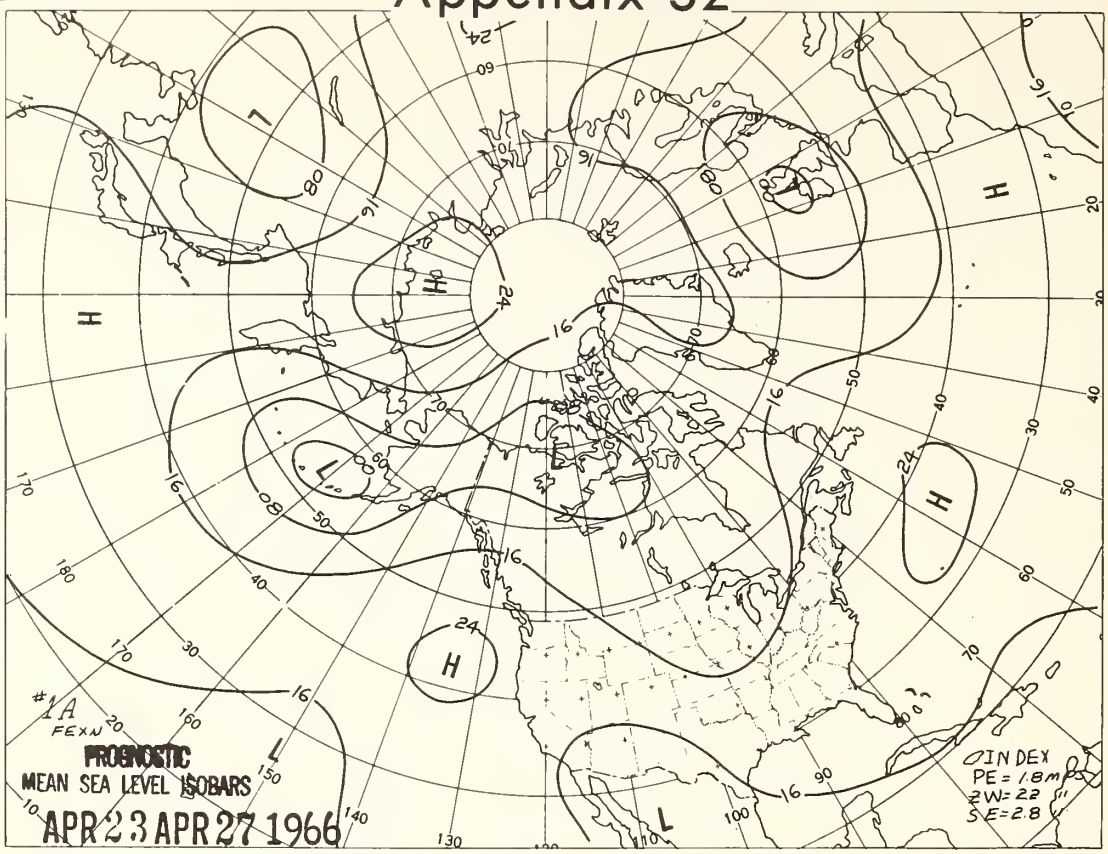

FAX MAP NO. 35
OBSD 5-DAY MEAN
SEA LEVEL
700 MB
APR 23 APR 27 1966

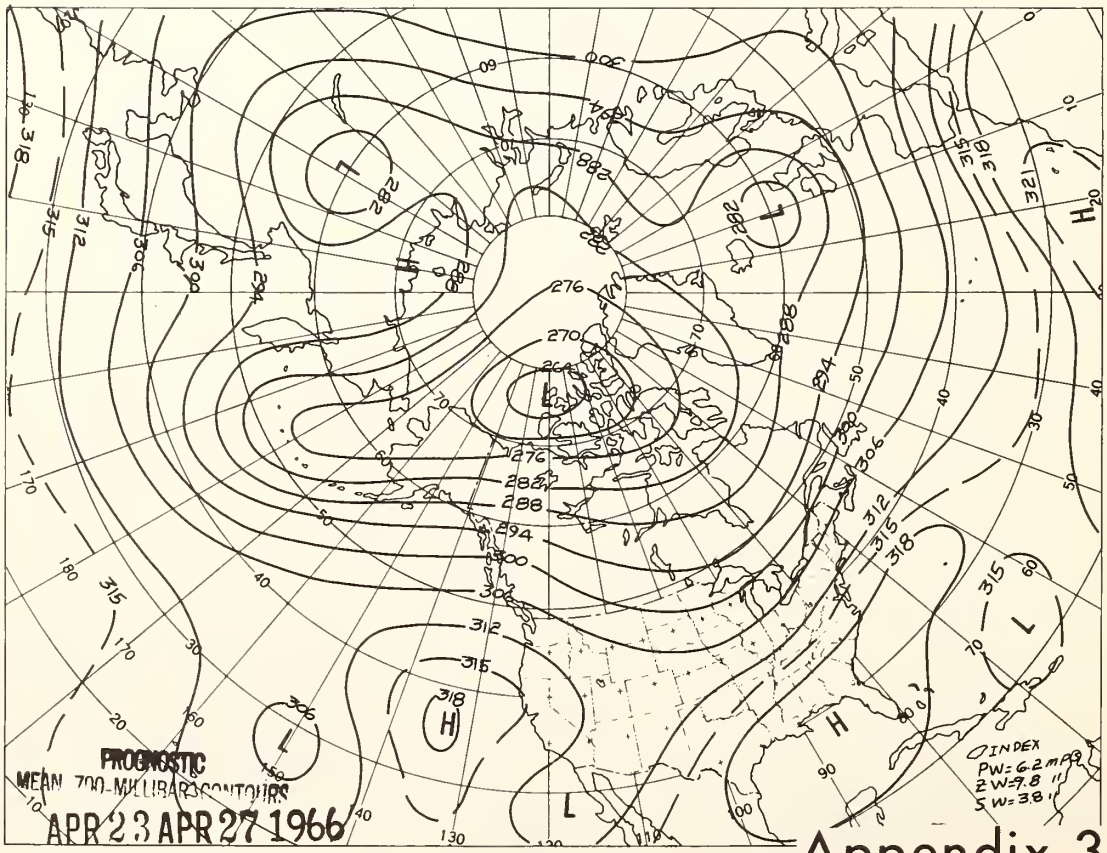

OBSD MEAN TEMP
APR 23 APR 27 1966
CXXN NMC
OBSD 5-DAY PRECIP
APR 23 APR 27 1966

Appendix 31



Appendix 31

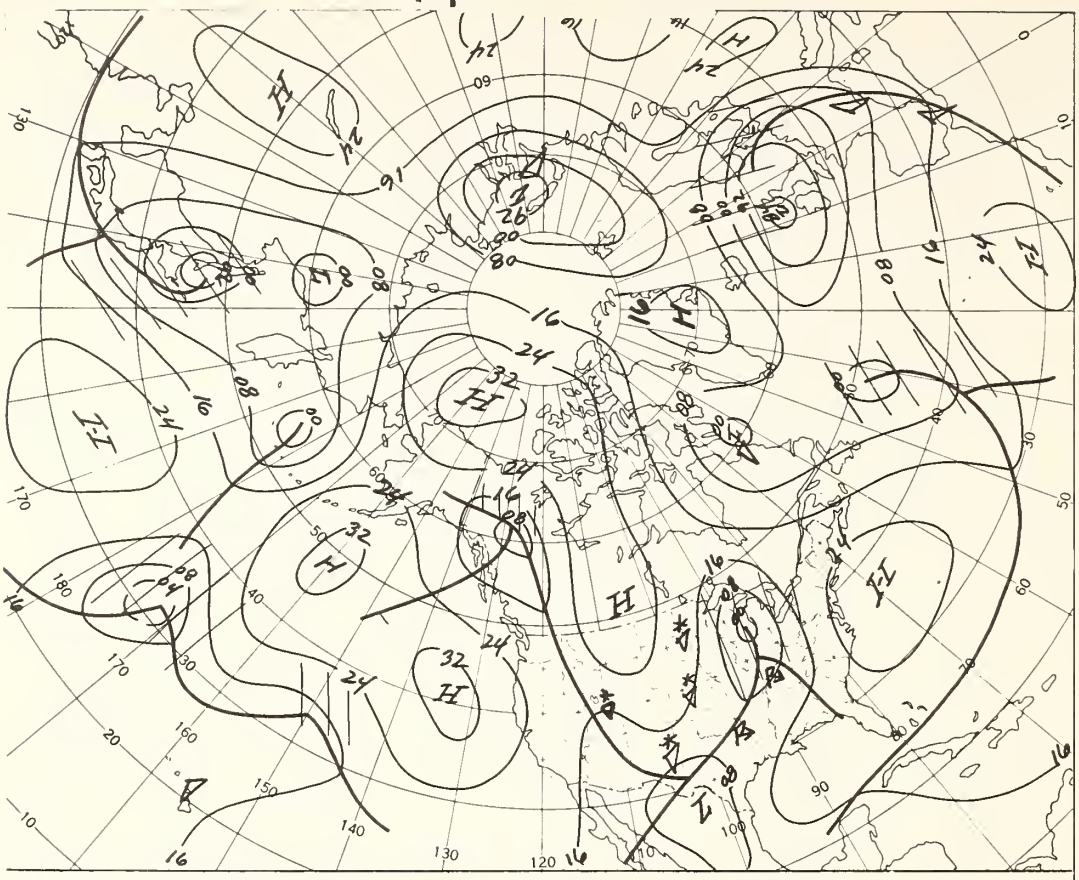

#1A
FEXN
PROGNOSTIC
MEAN SEA LEVEL ISOBARS
APR 23 APR 27 1966
INDEX
PE = 1.8 m
2W = 2.2 "
SE = 2.8 "


PROGNOSTIC
MEAN 700-MILLIBAR CONTOURS
APR 23 APR 27 1966
INDEX
PW = 6.2 m
2W = 7.8 "
SW = 3.8 "

Appendix 33

262
FAX MAP NO 42
#1B
ABOVE
NEAR NORMAL
BELOW
PROG MEAN TEMP
APR 23 APR 27 1966
NP
LIGHT
MODERATE
HEAVY
PRECIPITATION
NO PRECIPITATION
FEXN NMC
PROG 5-DAY PRECIP
APR 23 APR 27 1966
SAT APR 23 1966

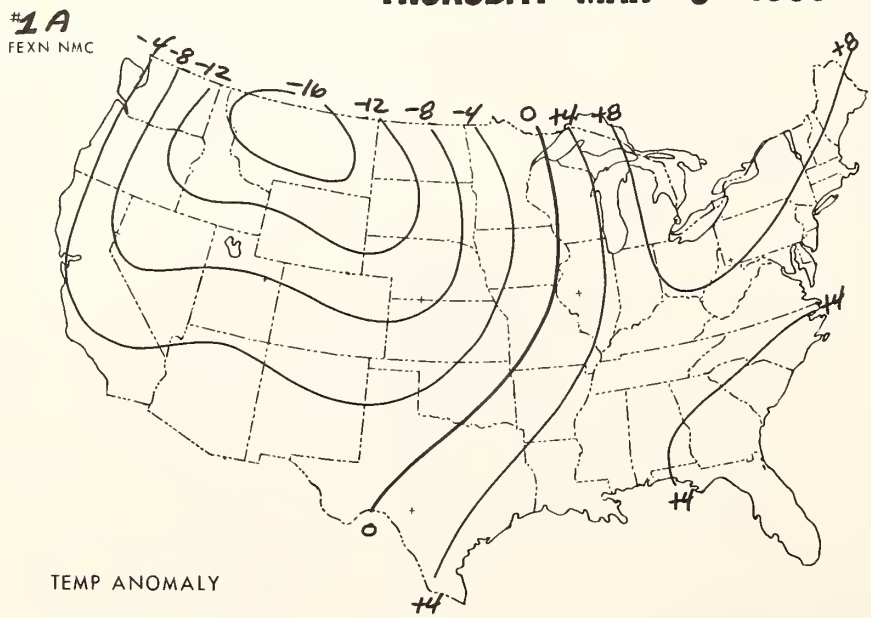
Appendix 34



FAX MAP NO. 48

72 HR. SFC PROG V. T. 12Z

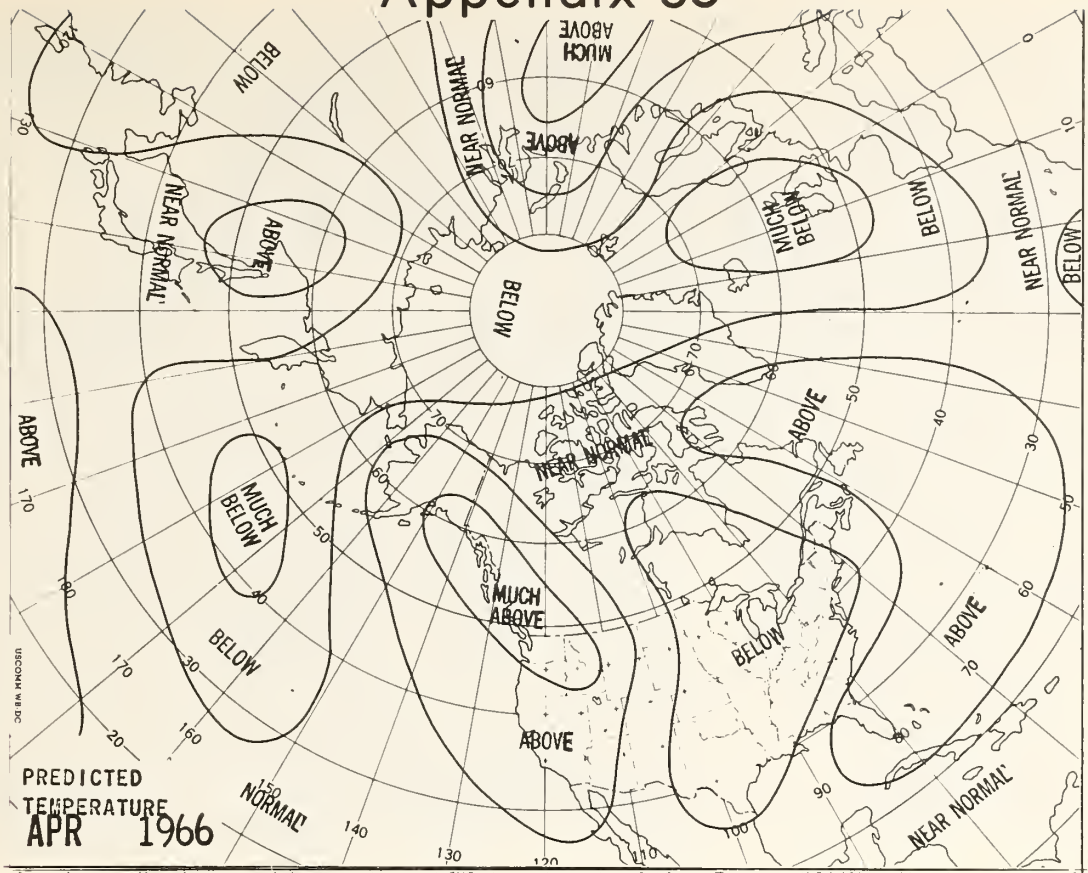
THURSDAY MAR 3 1966

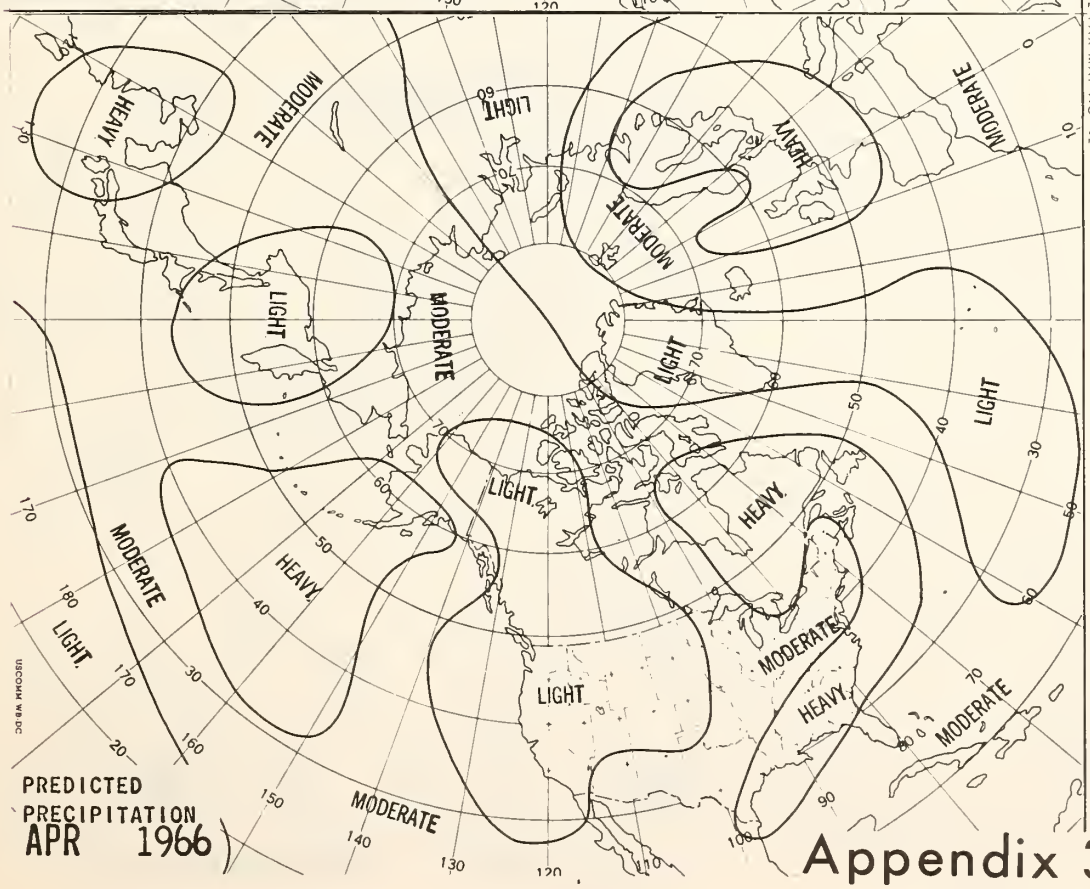


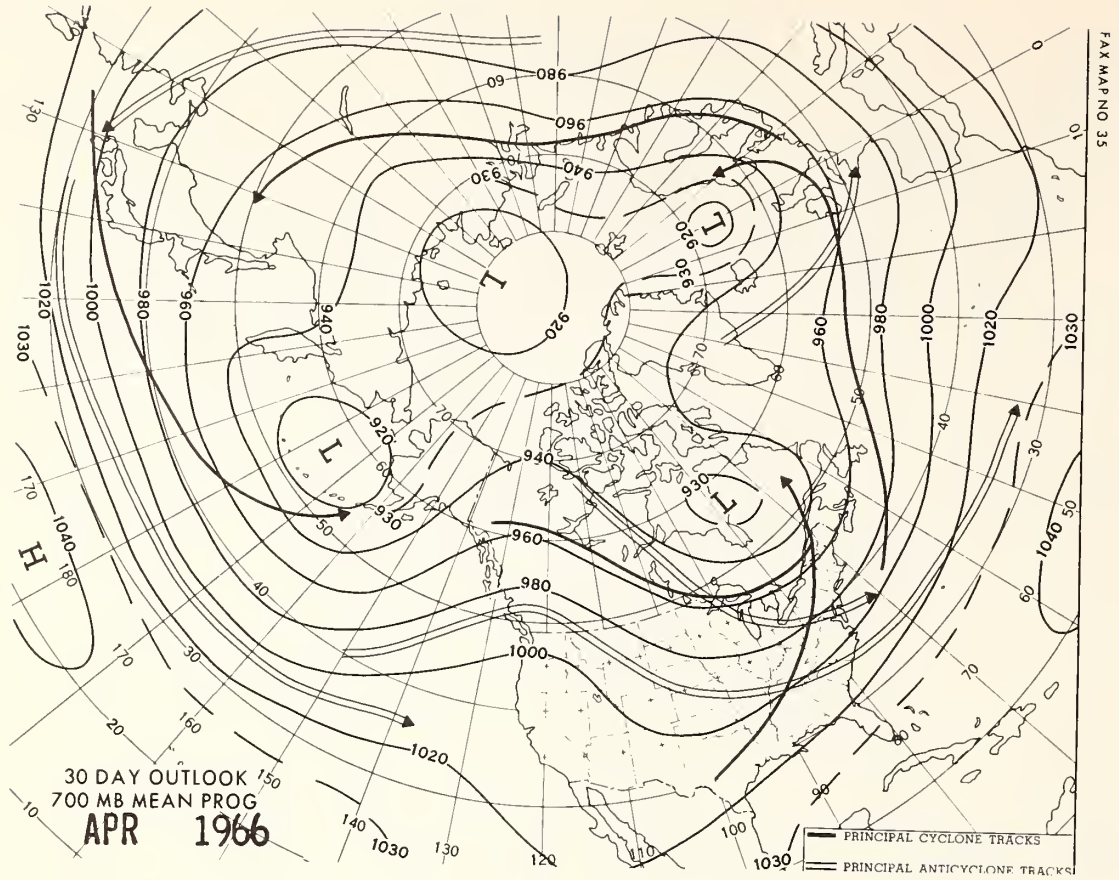
TEMP ANOMALY

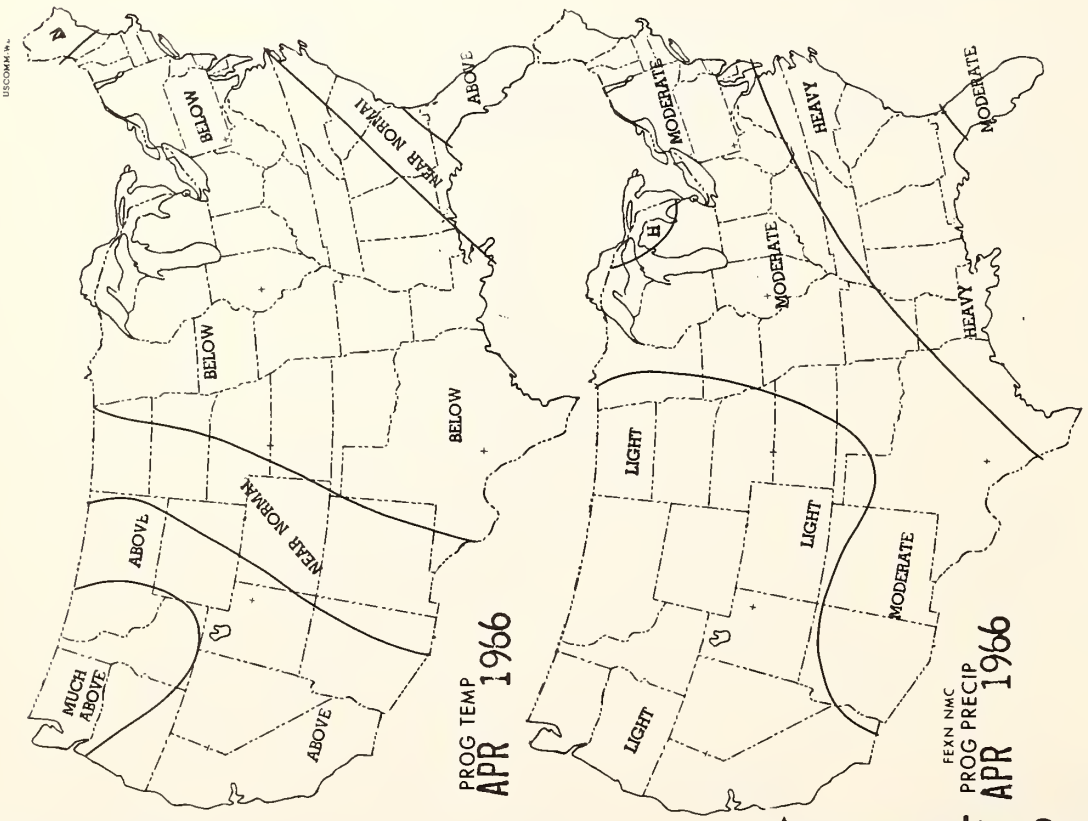
USCOMM-WB DC

Appendix 34

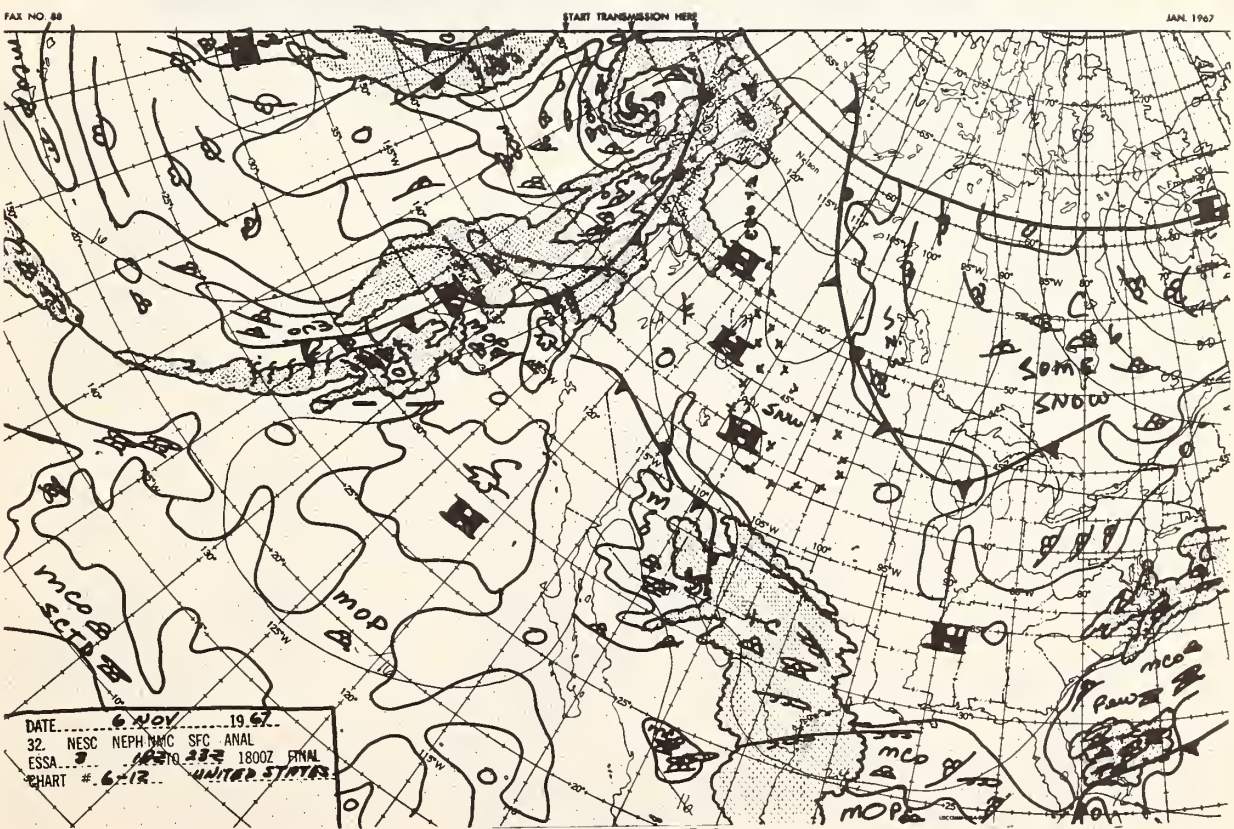

PREDICTED
TEMPERATURE
APR 1966
MUCH ABOVE
ABOVE
NEAR NORMAL
BELOW
MUCH BELOW
FAX MAP NO. 42


PREDICTED
PRECIPITATION
APR 1966
HEAVY
MODERATE
LIGHT
FAX MAP NO. 42


FAX MAP NO 35
30 DAY OUTLOOK
700 MB MEAN PROG
APR 1966
PRINCIPAL CYCLONE TRACKS
PRINCIPAL ANTICYCLONE TRACKS


PROG TEMP
APR 1966
FEXN NMC
PROG PRECIP
APR 1966
BELOW
NEAR NORMAL
ABOVE
MUCH ABOVE
LIGHT
MODERATE
HEAVY

Appendix 35



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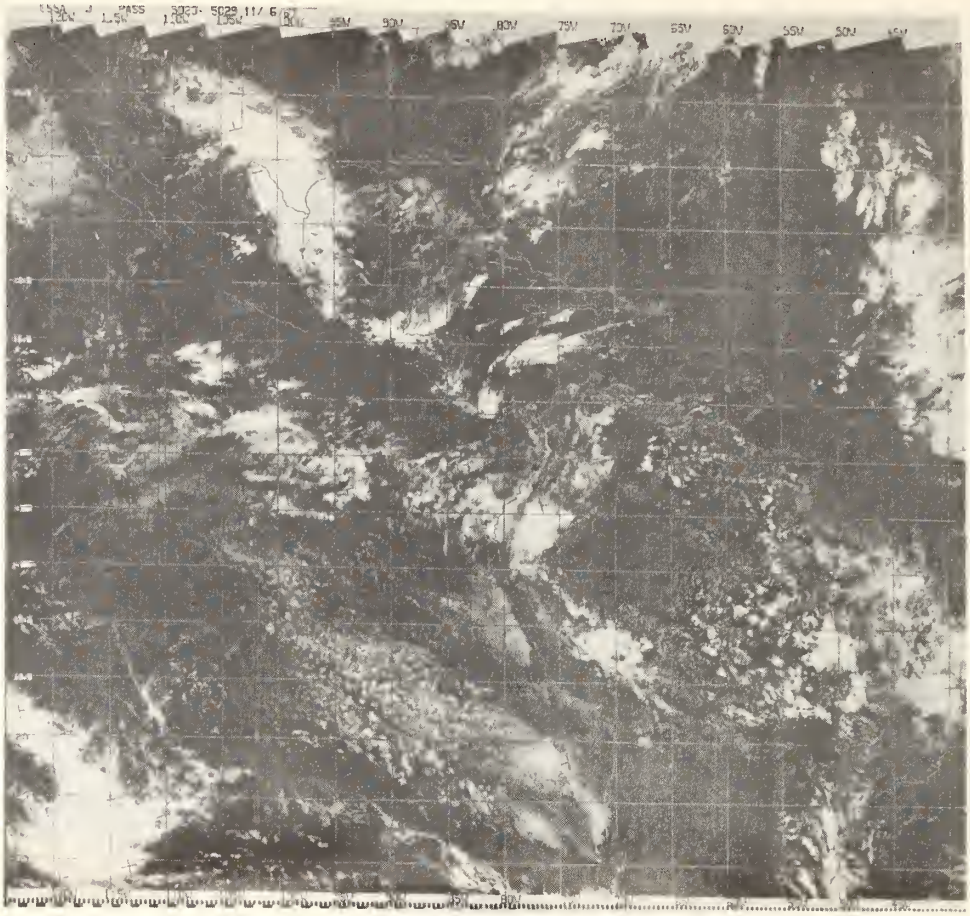
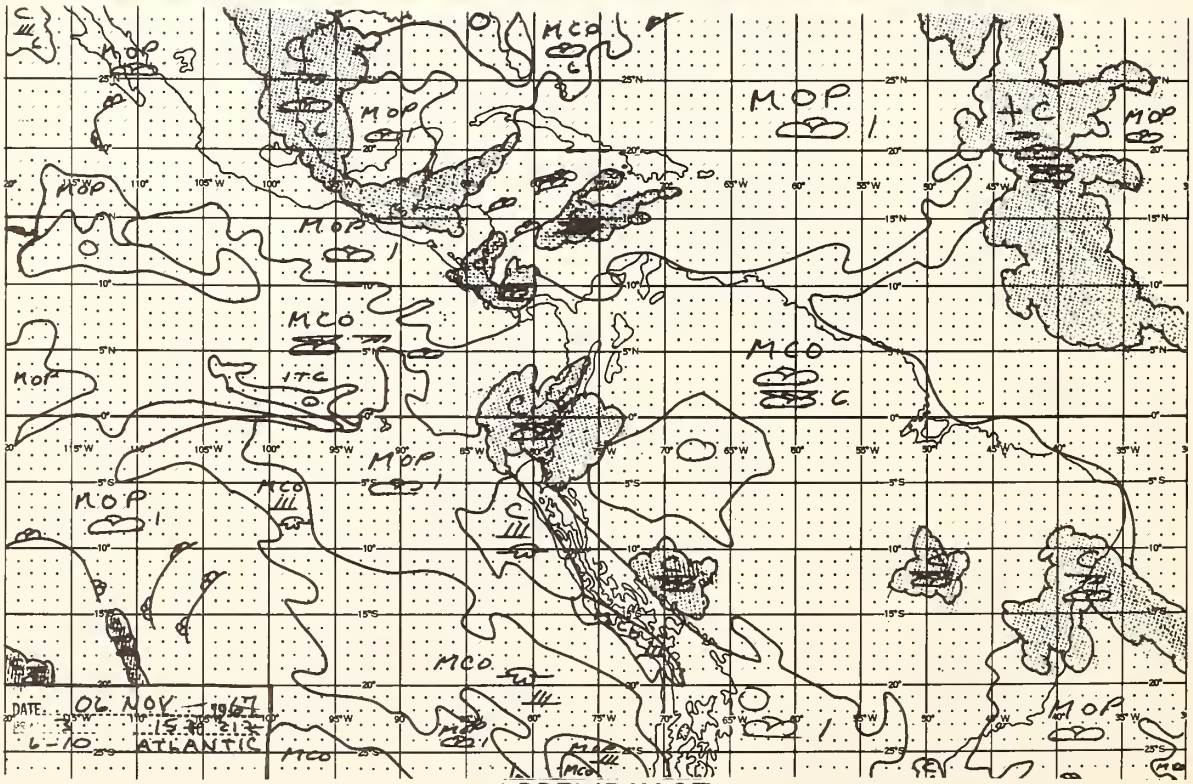
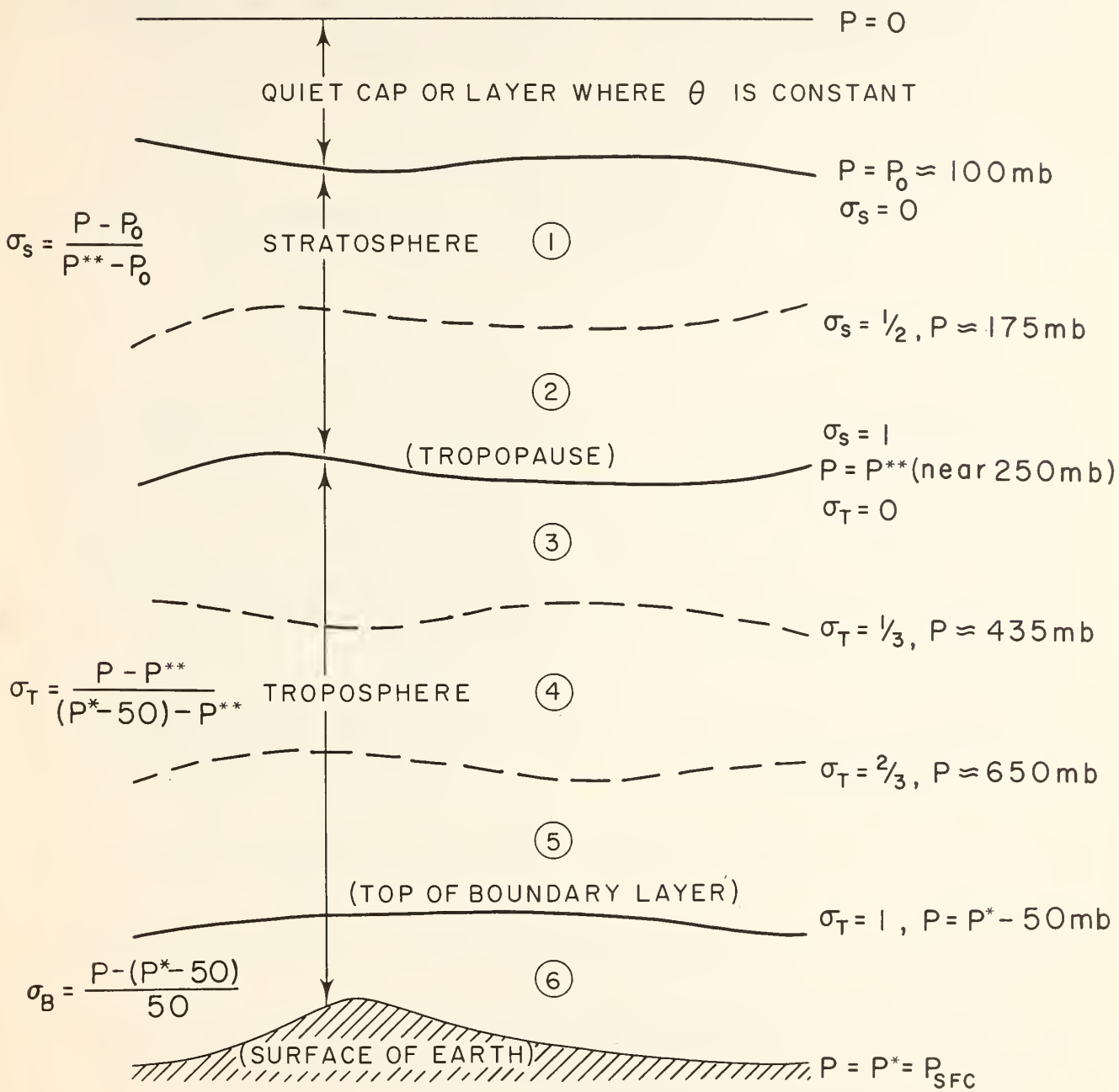




APPENDIX 37

Appendix 39

SCHEMATIC DIAGRAM OF STRUCTURE OF 6-LAYER (PE) NUMERICAL PREDICTION MODEL



Appendix 39

APPENDIX 40

COMPUTATION AND ANALYSIS OF PRECIPITABLE WATER

The amount of precipitable water is computed from all radiosonde observations over the United States and southern Canada. The method of computation is adopted from that derived by Solot (1). His conclusion is that:

$$W = 0.0004\ q\ \Delta P$$

where W = precipitable water (inches)

w = mixing ratio which is $\approx$ to specific humidity (q) (grams/kilogram)

If we set $\Delta P = 250$ mb, then

$$W = 0.1w$$

In practice a transparent overlay with horizontal parallel lines marked off coinciding with the 1000 mb, 750 mb, and 500 mb levels (i.e., 250 mb increments of pressure altitude) on the pseudo-adiabatic chart is used. It also contains a sloping straight line corresponding to the mean slope of the saturation mixing ratio lines. This overlay is placed over each sounding so that the straight sloping line forms equal areas on either side of a mixing ratio line for each 250 mb increment. The value of the precipitable water (in inches) for each increment is one-tenth that of the value of the mixing ratio line about which the equal areas are formed. The sum of the two increment values is then plotted on a chart for analysis.

In the cases of soundings at high-elevation stations the portion of the sounding below the 750 mb level does not constitute a 250 mb layer. Therefore, the computed precipitable water value is too great for the air column involved and it is reduced in the same ratio that the depth of the layer is to 250 mb.

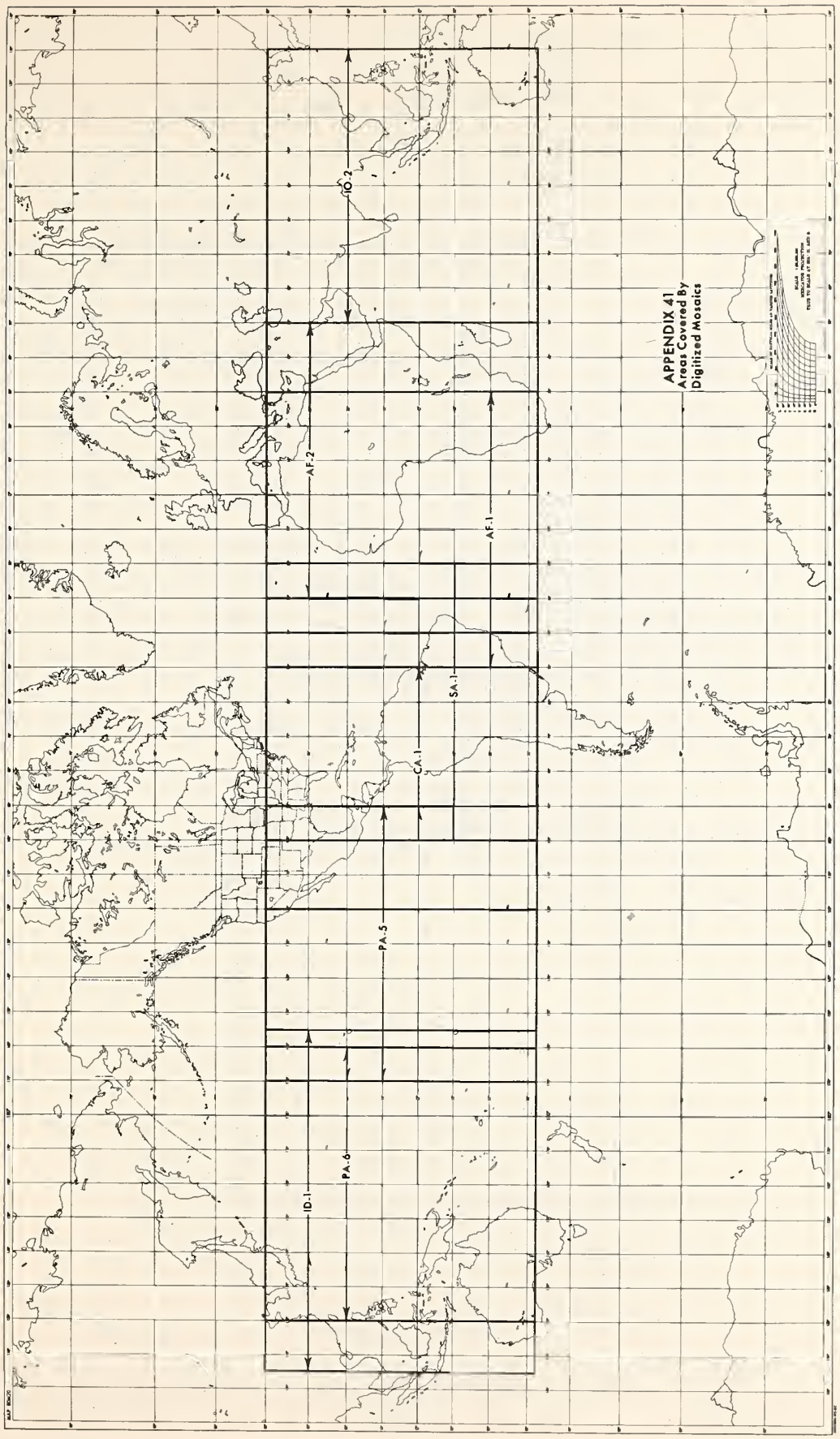
In cases of "motor boating," dewpoint values are assumed to be 20° C or 30° C lower than the air temperature when the latter is below or above 10° C, respectively.

Whenever values of precipitable water are less than .20 inch this extremely dry condition is indicated by plotting the symbol "D".

After all computations have been made and plotted, isopleths of W are drawn using direct analysis procedures for .50 inch intervals. Isopleths for .25 inch intervals are drawn if necessary to define the pattern.

REFERENCE:

Solot, S. B., "Computation of Depth of Precipitable Water in a Column of Air", Monthly Weather Review, April 1939, pp. 100-103.


APPENDIX 41
Areas Covered By
Digitized Mosaics
10-2
AF-2
AF-1
SA-1
CA-1
PA-5
PA-6
ID-1

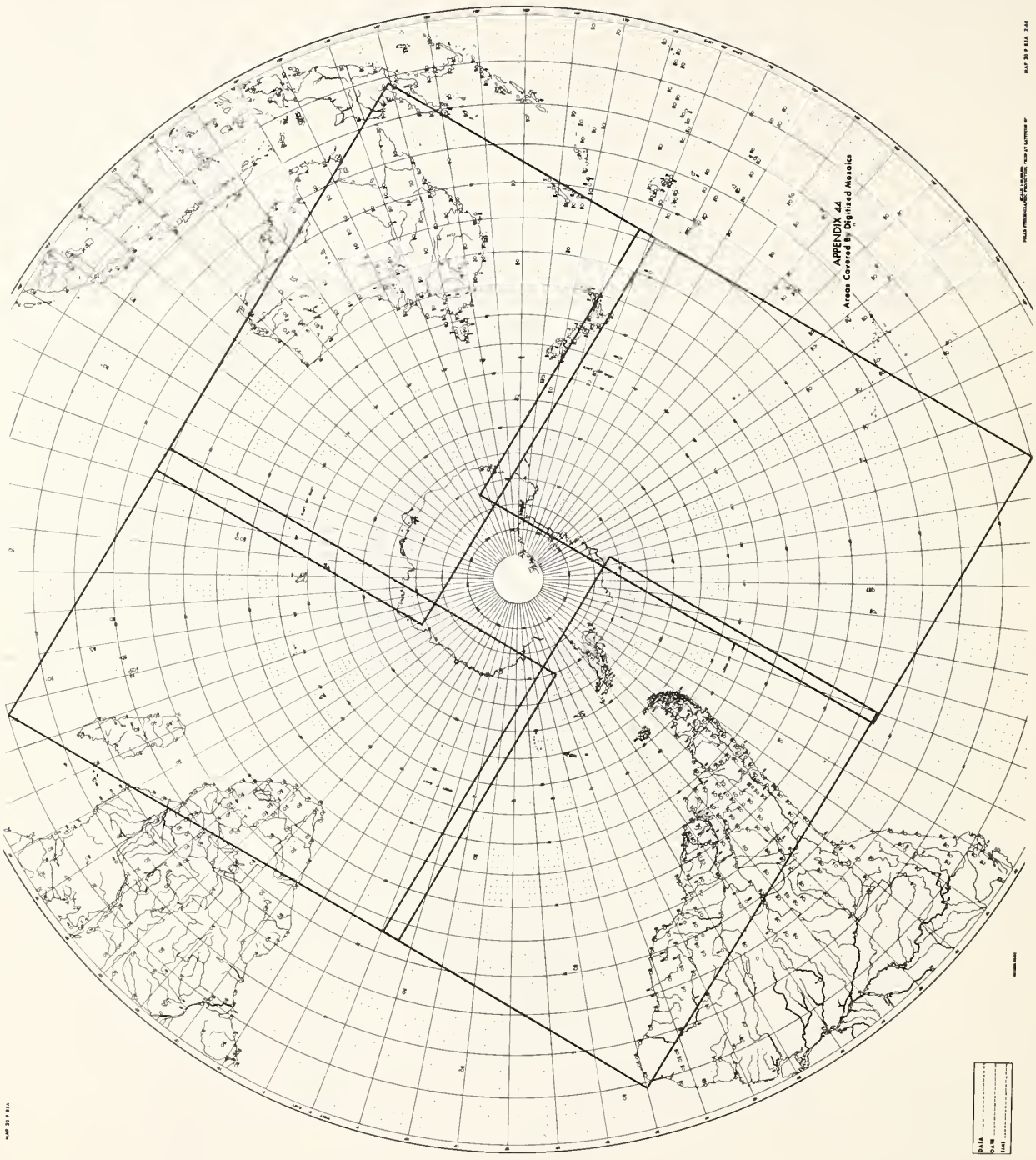
APPENDIX 42

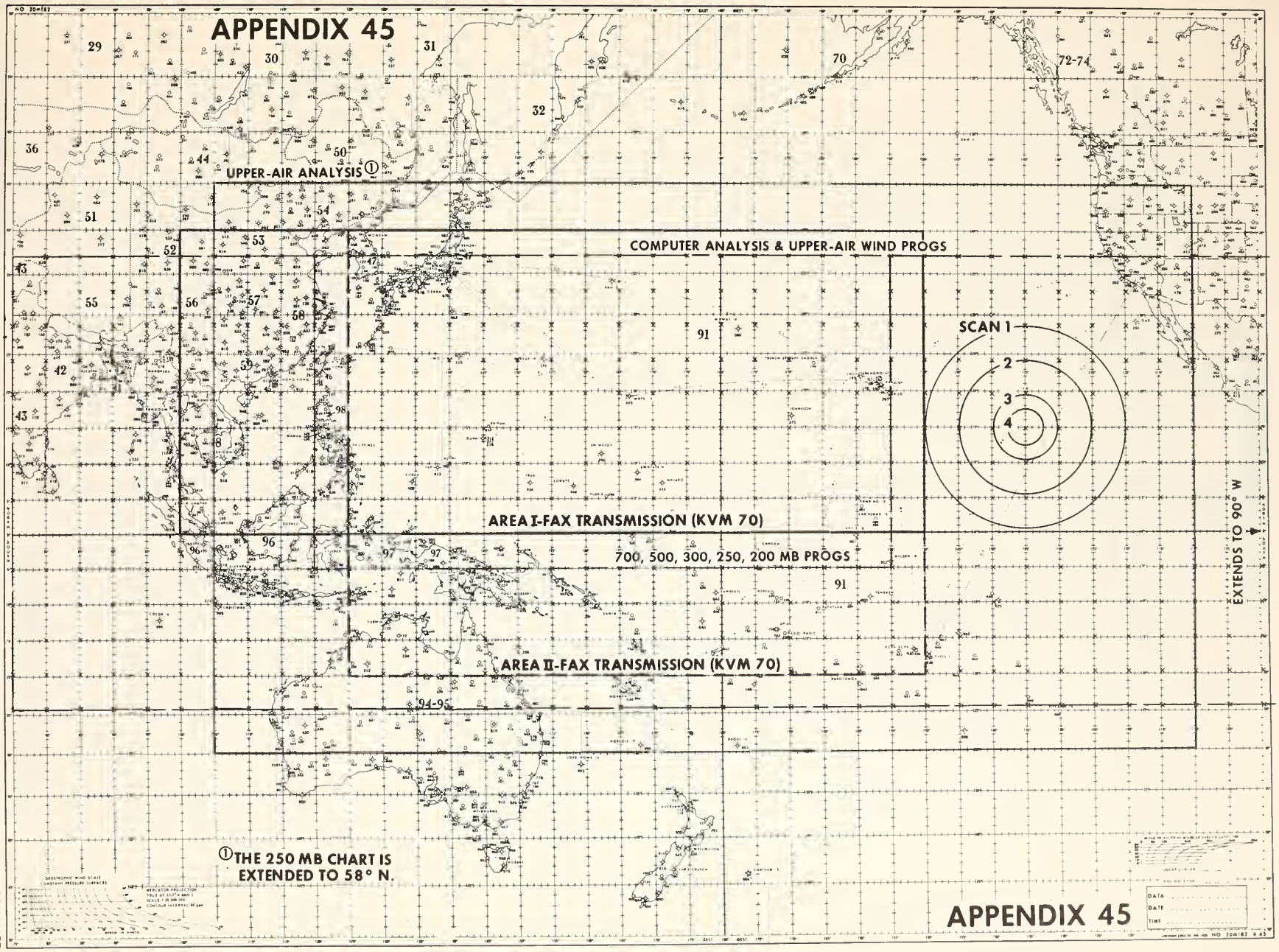
AREAS COVERED BY DIGITIZED MOSAICS

Additional Areas On APPENDIX 43

APPENDIX 43

AREAS COVERED BY DIGITIZED MOSAICS
Additional Areas On APPENDIX 42


APPENDIX 44
Areas Covered by Digitized Mosaics



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APPENDIX 46

TABLE 1

1000 MB HEIGHT METERS	SEA LEVEL PRESSURE MBS	1000 MB HEIGHT METERS	SEA LEVEL PRESSURE MBS
+ 30	1003.5	- 30	996.5
60	1007.5	60	993
90	1011.5	90	988.5
120	1015	120	985
150	1018.5	150	981.5
180	1022	180	978
210	1026	210	974
240	1029.5	240	970.5
270	1033	270	967
300	1037	300	963

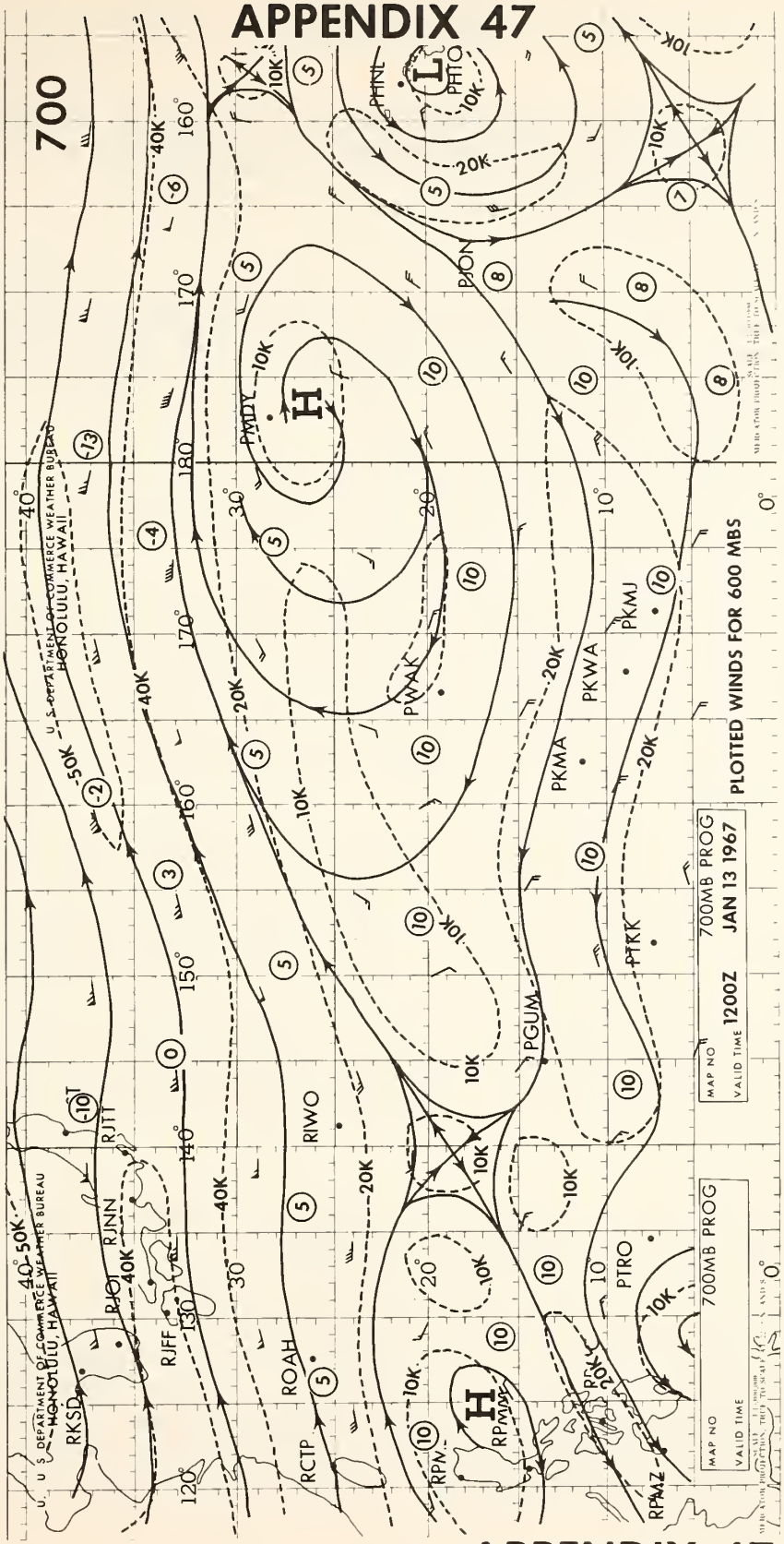
TABLE 2

1000-250 MB THICKNESS (m)	1000-500 MB THICKNESS (m)
11040	5860
10980	5830
10920	5800
10800	5740
10680	5680
10560	5620
10440	5560
10320	5500
10200	5440
10080	5380
9960	5320
9840	5260
9720	5200
9600	5140

Table 1. Height (m) of 1000 mb surface based upon sea level pressure in millibars and a temperature of 15°C.

Table 2. Relationship of 1000-250 mb thickness (m) to 1000-500 mb thickness (m).

APPENDIX 46


700
U. S. DEPARTMENT OF COMMERCE WEATHER BUREAU
HONOLULU, HAWAII
PLOTTED WINDS FOR 600 MBS
700MB PROG
MAP NO
VALID TIME 1200Z JAN 13 1967
RKSD
RJOI
RJNN
RJFF
RJTT
ROAH
RIWO
RCTP
PWAK
PMDY
PHNL
PHTO
PJON
PKMA
PKWA
PKMJ
PTKK
PGUM
PTRO
RPMZ

APPENDIX 47

APPENDIX 48

DESCRIPTION OF COMPUTER-PRODUCED AND MANUALLY-PRODUCED UPPER-AIR WIND AND TEMPERATURE ANALYSES AT WBFC HONOLULU

A. COMPUTER PRODUCTS

The charts in this series are the 700, 500, 400, 300, 250, and 200 mb wind barb charts. Isotherm charts are available on demand. The area analyzed by the computer extends from 75° E to 90° W and from 24° S to 37° N on a 1:20 million scale Mercator chart at 0000Z and 1200Z. (See appendix 45.)

Computations are carried out on a tropical grid of 14 X 40 points as shown in appendix 45. Points are 300 miles apart at the equator. Only large scale motions can be depicted by such a grid.

The analyses are based on an automatic data processing program which begins 3 hours 30 minutes after nominal observation time. However, because the bulk of available data are AIREPS, the availability of upper soundings is less critical than with high latitude analyses. These data are received via conventional circuits and from an FNWF, Monterey, editing of the Air Force high speed AW net from Tinker AFB Oklahoma. Approximately 500 AIREP and upper air reports are used in each run.

Analysis of each level is carried out in a manner similar to that used at NMC (see "WBFH Number 1 - Facsimile Products", UA-1, UA-2). AIREP winds and temperatures are adjusted to the nearest analyzed level using latest available shear fields. Wind analyses are obtained by analyzing u and v component scalar fields separately and recombining these to produce wind speed and direction values at grid points. The "guess" field consists of the previous analysis with a gradual return toward climatology (5% per six hours time increment since last analysis). Computations are made on a Navy-owned CDC-3100 at Fleet Weather Central, Pearl Harbor, Hawaii, under a Weather Bureau, Navy, Air Force cooperative arrangement.

An example of a machine plotted wind-barb chart with objectively produced streamlines is shown in Figure 1.

Because of the lack of quality control on AIREPS, it is necessary to manually monitor production of these products. Grossly unreasonable AIREPS are eliminated, and the effects of unreasonable reports that inadvertently get into the analysis are eliminated by modifying the analysis ex post facto to ensure a better "guess" for future runs. Tropical storm circulations are "forced" into the analysis using subjective modeling techniques.

The output from these analyses are also widely distributed in "paper doll" teletype form. An example is shown in Figure 2.

REFERENCE:

1. Bedient, H. A., and Vederman, J., "Computer Analysis and Forecasting in the Tropics", Monthly Weather Review, Volume 92, No. 12, December 1964, pp 565-577.

B. MANUAL PRODUCTS

These products are:

a.	250 mb (300 mb, 200 mb)	- Basic analysis, streamlines between 20° S and 20° N merged with 120 meter contours beyond these latitudes, 5° C isotherms.
b.	500 mb	- Streamlines between 20° S and 20° N merged with 60 meter contours beyond these latitudes, 5° C isotherms.
c.	700 mb	- Streamlines between 20° S and 20° N merged with 60 meter contours beyond these latitudes, 5° C isotherms.

The charts are hand plotted and analyzed (using computer wind printout as an underlay) on a 1:20 million scale Mercator chart (true at 22.5 latitude) at 0000Z and 1200Z. (See appendix 45.) At 0600Z and 1800Z plotted charts are also produced and analyzed.

Plotting Procedures

1. NETWORKS:

All available radiosonde, rawinsonde, pibal, de-briefing, and weather reconnaissance reports are plotted by hand. 300, 250, and 200 mb data are plotted on the 250 mb chart.

2. MODEL:

The station models used to plot radiosonde, rawinsonde, pibal, and weather reconnaissance reports are shown in a, b, c, and d of Figure 3. Item "e" of Figure 3 describes the altitude range of aircraft reports that are plotted at the various constant pressure surfaces.

3. DEADLINES:

Deadline for entering all data on the hand plotted and analyzed charts is 4 1/2 hours after observation time on 250 mb; and 5 hours after observation on 700 mb and 500 mb charts.

Philosophy of Analysis

80-90 percent of jet aircraft flights over the Pacific are made within 3,000 feet of the 250 mb level. Because of this, the 250 mb level has been selected for the basic upper air analysis. The purpose of the intermediate 0600Z and 1800Z charts is to maintain continuity. The machine analysis is the primary tool used in preparation of hand analyses. Where differences exist, a suitable compromise is made. The main contribution of the analyst is to adjust the shape, gradients, etc., of the computer output and to strive for a vertically consistent portrayal of the atmosphere. At 500 mb, and even more so at 700 mb, much less data are available than at the surface or jet aircraft level (near 250 mb) in the Tropical Pacific. Hence the analyst relies more on assistance from the surface and 250 mb levels than is ordinarily the case. The following procedures are subject to modifications as machine analyses improve in reliability and timeliness.

Analysis Procedures

250 mb chart

1. TIME AVAILABLE:

   One analyst completes the combined 300-250-200 mb chart in 1 1/2 hours or about 6 hours after observation time.

2. TOOLS AVAILABLE:

   a. 1000 mb chart generated by converting the surface pressure analysis according to the values from appendix 46, Table 1.

   b. 1000-250 mb thickness chart with a contour interval of 120 meters for the corresponding time.

   c. NMC higher latitude analysis and prognosis charts as received via facsimile.

   d. Previous analyses.

   e. Tropical Pacific objective analysis from local computer center.

   f. Satellite nephanalyses and APT cloud pictures.

3. PROCEDURES:

   0000Z and 1200Z

   a. The preliminary 250 mb contour pattern north of 20° N is obtained by adding graphically the 1000 - 250 mb thickness pattern to the 1000 mb contour pattern.

b. All available NMC and local objective analysis and forecast guidance materials are used plus continuity to estimate the tropical streamline pattern between 20° S and 20° N.

c. Contours and streamlines are adjusted to fit plotted data.

d. The analysis of temperature field is prepared using 5° C isotherms, noting the similarity of the 1000 - 500 mb thickness pattern to the 250 mb isotherm pattern.

e. When the objective analysis is available, the differences are compromised and the analysis is adjusted.

0600Z and 1800Z

Using previous analysis for continuity, the contours, and streamlines are sketched. This chart is for local use only.

500 mb chart

1. TIME AVAILABLE:

One analyst completes the 700 and 500 mb analysis charts in about 1 1/2 hours or about 6 hours after observation time.

2. TOOLS AVAILABLE:

a. 1000 mb chart generated by converting the surface pressure analysis according to the values from appendix 46, table 1.

b. 1000 - 250 mb thickness chart for the corresponding time is statistically converted to 1000 - 500 mb thickness using table 2 of appendix 46.

c. NMC higher latitude analysis and prognosis charts as received via facsimile.

d. Previous analyses.

e. Tropical Pacific objective analysis from local computer center.

f. Satellite nephanalyses and APT cloud pictures.

3. PROCEDURES:

a. Using the relationships shown in table 2 of appendix 46, the 1000 - 250 mb thickness is converted to 1000 - 500 mb thickness which is adjusted by available data and added to the 1000 mb to obtain estimate of the 500 mb contours.

b. Using the estimated 500 mb analysis as a first approximation, a contour analysis is drawn considering data, slopes of ridges, troughs and neutral points. Special consideration is given to insuring that tropical low centers slope appropriately.

c. The streamline pattern in the region 20° S to 20° N is analyzed paying particular attention to stream patterns at 250 mb to prevent unusual shear situations.

d. All available NMC and local objective analysis and forecast guidance material is used plus continuity to estimate tropical streamline pattern between 20° S and 20° N.

e. The temperature field is analyzed and depicted by 5° isotherms. This temperature field is highly correlated with the 1000 - 250 mb thickness as shown in table 1, figure 4.

700 mb chart

1. TIME AVAILABLE:

One analyst completes the 700 and 500 mb analysis charts in about 1 1/2 hours or about 6 hours after observation time.

2. TOOLS AVAILABLE:

a. 1000 mb chart generated by converting the surface pressure analysis according to the values from appendix 46, table 1.

b. 1000 - 250 mb thickness chart with a contour interval of 120 meters for the corresponding time.

c. NMC higher latitude analysis and prognosis charts as received via facsimile.

d. Previous analyses.

e. Tropical Pacific objective analysis from local computer center.

f. Satellite nepahanalyses and APT cloud pictures.

3. PROCEDURES:

a. Height contour analysis is prepared for the region north of 20° N using 1000, 250, and thickness charts as guidance. Objective guidance materials, as available, from NMC and Fleet Weather Central, Pearl Harbor, are used. Occasionally, the 1000 - 500 mb chart obtained by graphical addition is converted to 700 mb chart using the conversion values shown in table 2, figure 4.

b. A streamline analysis in area 20° S to 20° N is drawn and merged with higher latitude contours. Positions of major tropical circulation features on available higher level charts and the surface chart are considered. Tropical storms are computed to show the minimum height and maximum temperature according to figure 5.

c. Isotherms are drawn for every 5° C subjectively using 1000 - 500 mb thickness pattern as a guide. This procedure is based on the assumption that thickness contours and isotherms are generally parallel in the low latitudes.

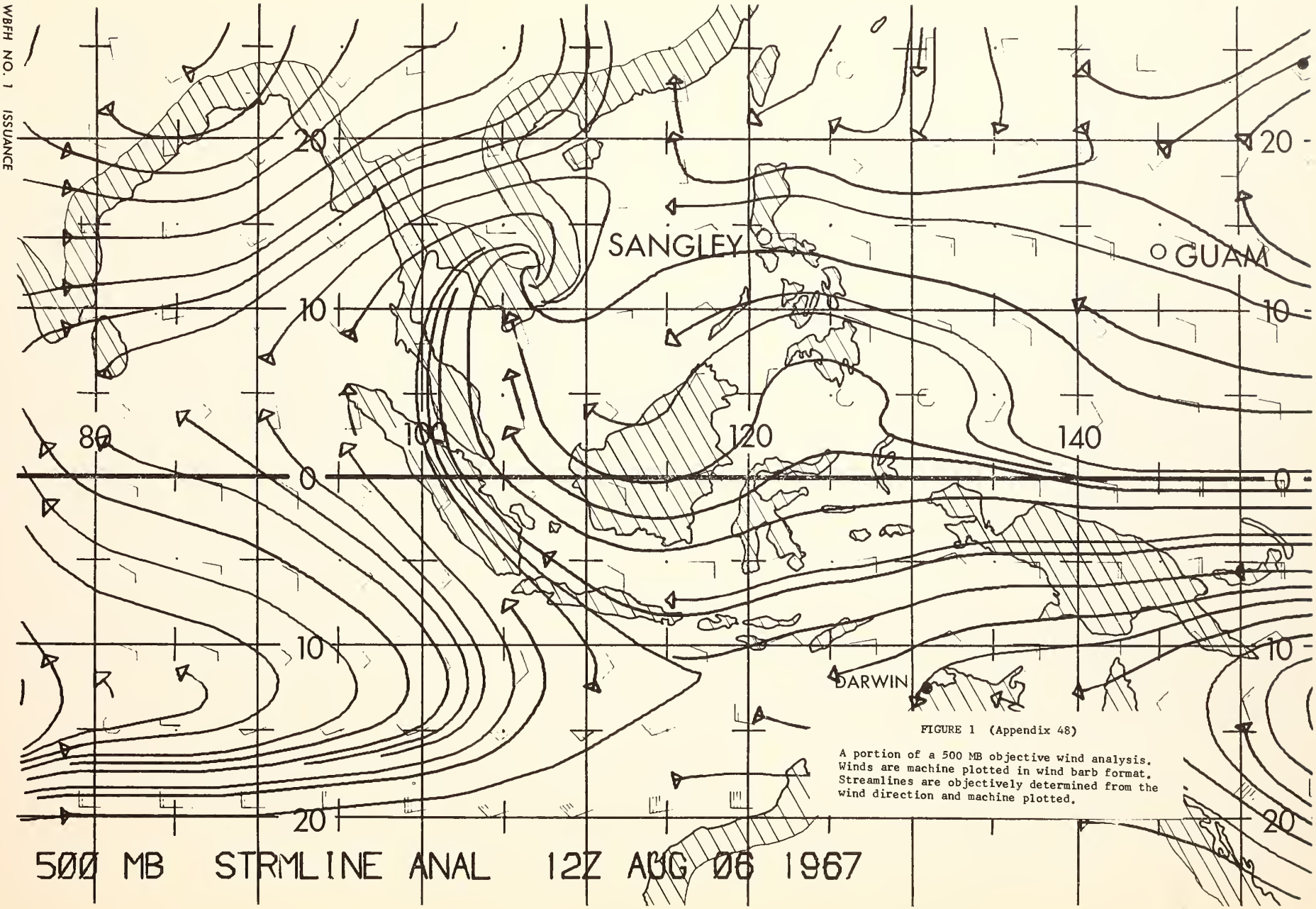


FIGURE 1 (Appendix 48)

A portion of a 500 MB objective wind analysis. Winds are machine plotted in wind barb format. Streamlines are objectively determined from the wind direction and machine plotted.

FIGURE 2 (Appendix 48)

Small section of a typical "paper doll" teletype bulletin containing upper wind and temperature information. Seven similar sections cover the Tropical Pacific and Indian Oceans from 75°E to 90°W and 24°S to 37°N. Message format is designed to permit direct overlay of the grid on a standard 1:20M Mercator projection.

```
SXN 7        100E        105E        110E        115E        120E

↑46 08022 ↑47 08014 ↑47 09007 ↑48 09009 ↑49 10016 ↑51 10031
↑34 08021 ↑37 08012 ↑36 07008 ↑37 13007 ↑37 15013 ↑38 09019
↑25.08014 ↑26.09012 ↑25.09010 ↑27.09026 ↑27.11020 ↑29.07021 24.2
↑01 22003 ↑01 01002 ↑01 15006 +00 16020 ↑01 07014 ↑03 05012
+13 21004 +10 16004 +12 25008 +11 16008 +12 12010 +11 03014

↑51 08027 ↑50 10016 ↑50 07013 ↑49 08009 ↑51 07011 ↑51 07028
↑38 08023 ↑38 07013 ↑38 06008 ↑38 11014 ↑39 13010 ↑37 06009
↑28.08021 ↑28.07016 ↑28.07010 ↑25.08010 ↑28.07011 ↑24.10018 19.6
↑03 17002 ↑02 22002 ↑02 15008 ↑02 19004 ↑03 15019 ↑04 31002
+10 20003 +11 06003 +11 15003 +11 21008 +10 12011 +09 34009

↑52 08028 ↑52 09014 ↑51 06008 ↑53 12015 ↑52 05026 ↑54 04017
↑38 07019 ↑37 06006 ↑38 04005 ↑40 12012 ↑38 10019 ↑40 07016
↑29.07020 ↑29.09018 ↑29.09014 ↑28.11011 ↑20.08017 ↑29.03012 14.8
↑04 06001 ↑04 08010 ↑03 11012 ↑03 09017 +00 09015 ↑05 10010
+10 28007 +09 03007 +10 10007 +09 13009 +11 11017 +07 11004

↑54 07037 ↑53 08028 ↑53 05028 ↑53 03010 ↑53 07016 ↑54 03014
↑39 06024 ↑39 07014 ↑40 04024 ↑39 06009 ↑38 12019 ↑39 10017
↑30.07023 ↑31.08017 ↑31.04015 ↑26.06015 ↑21.09015 ↑19.08020  9.9
↑04 12001 ↑05 01002 ↑06 24016 ↑03 27007 ↑03 02004 ↑02 07006
+09 28006 +08 31008 +06 23016 +09 22015 +08 27010 +08 07003

↑54 07035 ↑54 07031 ↑54 07015 ↑54 07024 ↑54 07021 ↑54 07024
↑42 07025 ↑41 07022 ↑41 07016 ↑41 08018 ↑40 08021 ↑41 08021
↑32.07012 ↑32.09006 ↑31.07014 ↑29.07018 ↑25.10022 ↑26.09016  5.0
↑05 17008 ↑06 19010 ↑05 22005 ↑05 30001 ↑04 08004 ↑04 09009
+09 28006 +08 29014 +08 27009 +08 25010 +08 26010 +07 23001
```

LEGEND

Data Model

(s) TT DDVVV (200 MB information)
(s) TT DDVVV (250 MB information)
(s) TT•DDVVV (300 MB information)
(s) TT DDVVV (500 MB information)
(s) TT DDVVV (700 MB information)

where:

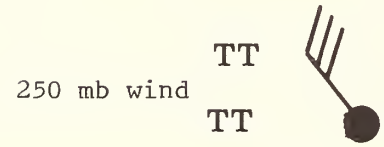
(s) - Sign (is -)
TT - Temperature °C
DD - Wind direction in tens of degrees
VVV - Wind speed in knots
• - Location of grid point where data available

FIGURE 3 (Appendix 48)

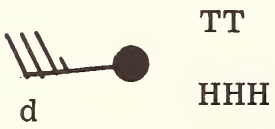
SUMMARY OF MODELS USED AT WBFC, HONOLULU FOR PLOTTING UPPER AIR DATA

a. 700 and 500 millibars:

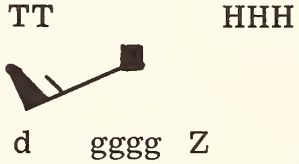
b. 300 - 250 - 200 mb data are plotted on same chart as follows:



c. All AIREPS are plotted as follows:



d. Reconnaissance data as available are plotted as follows:



e. Aircraft reports are plotted on constant pressure level charts as follows:

Altitude Range	Constant Pressure Level
8 - 12,000 feet	700 mb
16 - 20,000 feet	500 mb
27 - 32,000 feet	300 mb
33 - 37,000 feet	250 mb
37 - 43,000 feet	200 mb

FIGURE 4 (Appendix 48)

TABLE 1

1000-250 MB THICKNESS (m)	500 MB T (°C)
10870	- 5.0
10760	- 7.5
10660	-10.0
10560	-12.5
10460	-15.0
10360	-17.5
10260	-20.0
10160	-22.5
10050	-25.0
19950	-27.5

Table 1. Relationship of 1000-250 mb thickness (m) to 500 mb temperature (°C).

Table 2. Relationship of the sum of the 1000 mb and 500 mb heights to the 700 mb height (m).

TABLE 2

1000 MB + 500 MB (m)	700 MB (m)	1000 MB + 500 MB (m)	700 MB (m)
5160	2760	5940	3150
5280	2820	6000	3180
5400	2880	6060	3210
5520	2940	6120	3240
5640	3000	6180	3270
5760	3060	6240	3300
5880	3120	6300	3330

	SEA LEVEL		850 MB		700 MB		500 MB		300 MB		250 MB		200 MB	
	MBS	TEMP	HGT	TEMP	HGT	TEMP	HGT	TEMP	HGT	TEMP	HGT	TEMP	HGT	TEMP
WEAK	1000	+26	1400	+19	3050	+12	5790	-2	9660	-26				
	990	+26	1340	+20	2990	+13	5730	-1	9630	-25				
MODERATE	980	+26	1250	+21	2900	+14	5670	+1	9600	-23	10950	-34	12440	-46
	970	+26	1160	+21	2800	+15	5610	+3	9540	-22	10890	-34	12370	-46
	960	+26	1070	+22	2740	+16	5550	+5	9510	-22	10840	-34	12340	-46
INTENSE	950	+26	980	+22	2650	+16	5490	+5	9450	-22	10800	-34	12280	-45
	940	+26	880	+22	2560	+16	5430	+5	9390	-22	10720	-34	12220	-45
	930	+26	790	+22	2470	+16	5330	+5	9300	-22	10660	-34	12120	-45
	920	+27	730	+23	2380	+17	5270	+5	9240	-21	10580	-33	12070	-45
	910	+27	640	+23	2320	+17	5180	+6	9140	-21	10510	-33	12010	-44
SUPER	900	+27	550	+23	2230	+17	5120	+6	9050	-21	10410	-33	11920	-44
	890	+28	460	+24	2130	+18	5030	+7	8960	-20	10320	-32	11830	-43
	880	+28	370	+24	2040	+18	4970	+7	8900	-20	10260	-32	11770	-43

Relationship, in typhoons, of sea level pressure (mb) and temperature (°C) to heights (m) and temperatures (°C) at several levels.

FIGURE 5 (Appendix 48)

Surface Central Pressure and 700 mb Central Pressure (height) and temperature						
1000 mb	3050	+12	Normally the eye message	940 mb	2650	+16
990 mb	2990	+13	or the Japan marine bulletin	930 mb	2470	+16
980 mb	2900	+14	will give the minima. Check	920 mb	2380	+17
970 mb	2800	+15	these prior to making any	910 mb	2320	+17
960 mb	2740	+16	computations.	900 mb	2230	+18
950 mb	2650	+16		890 mb	2130	+18

APPENDIX 49

DESCRIPTION OF THE COMPUTER-PRODUCED 250 MB WIND FIELD FROM THE WBFC HONOLULU

The 24-hour computer wind forecasts of the Tropical Pacific are made utilizing a simple statistical scheme. This scheme postulates that the tropical atmosphere has a tendency toward return to climatological mean conditions. The rate of return is variable from point to point and can be stated in terms of a lag coefficient. Thus the forecast of the u, v wind components can be stated as

$$u_F = (1-r_u)\, u_c + r_u\, u_p$$

$$v_F = (1-r_v)\, v_c + r_v\, v_p$$

Where the subscript F refers to the forecast values of u and v, the subscript c to the monthly climatic mean wind value at a point, and p to persistence, r is the component lag coefficient determined by somewhat limited records at Tropical Pacific stations.

The machine output is made in the form of a machine plotted chart in which the wind data is plotted at each grid point denoted by a wind barb to show wind direction in tens of degrees and velocity in knots. (See Figure 1.) The prognoses are made twice daily for 0000Z and 1200Z on a 1:20 million scale Mercator chart extending from 75°E to 90°W and from 24°S to 37°N. (See appendix 45)

Detailed information on this forecast model is available in the following references:

REFERENCES:

1. Bedient, H. A., and Vederman, J., "Computer Analysis and Forecasting in the Tropics", Monthly Weather Review, Volume 92, No. 12, December 1964.

2. Lavoie, R. L., and Weideranders, C. J., "Objective Wind Forecasting Over the Tropical Pacific", University of Hawaii, Institute of Geophysics, Meteorology Division; #1, Contract AF 19(604)-7229, AFCRL-TN-60-832, Dec. 1960.

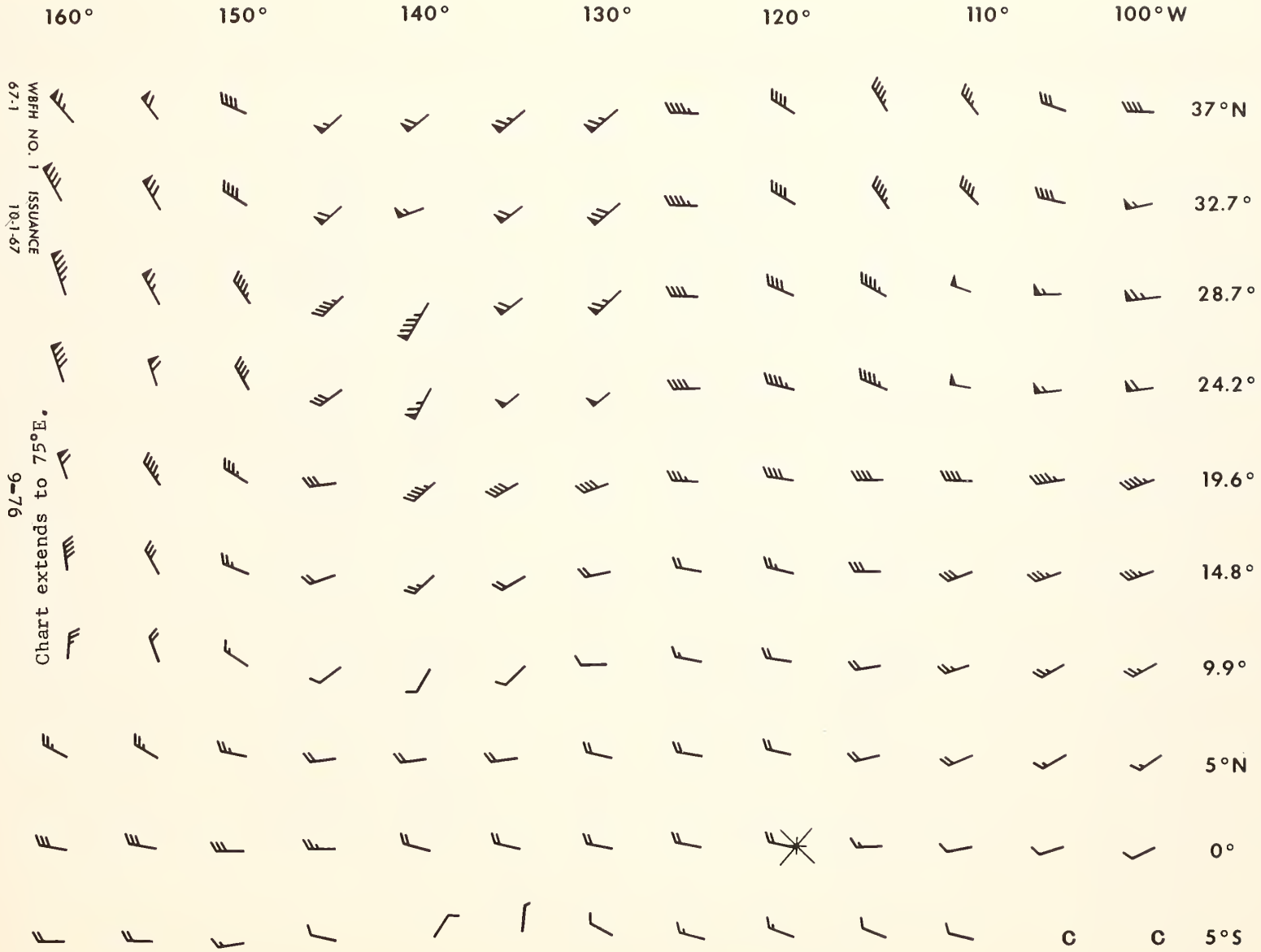


FIGURE 1. (Appendix 49)

250 MB FWC upper wind forecast 24 hours from 12Z 10 JAN 1967.

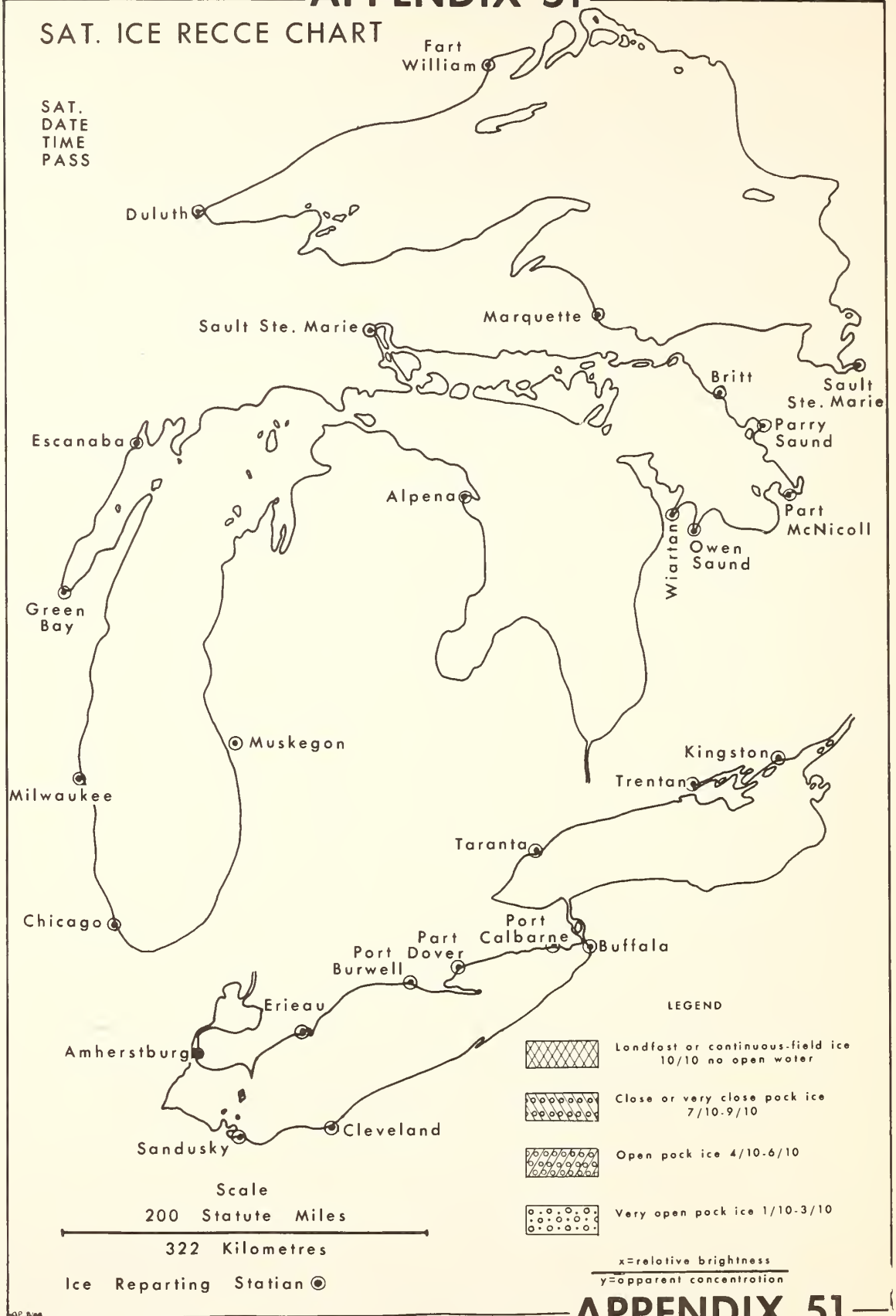
APPENDIX 50

250 MB (m)	300 MB (m)	200 MB (m)
11100	9840	12540
11040	9780	12480
10920	9660	12360
10800	9540	12240
10680	9420	12120
10560	9300	12000
10440	9180	11880
10320	9060	11760
10200	8940	11640
10080	8820	11520
9960	8700	11400
9840	8580	11280
9720	8460	11160
9600	8340	11040
9480	8220	10920
9360	8100	10800

Relationship of 300 mb height and 200 mb height to 250 mb height within temperature range -35° to -45°C at 250 mb.

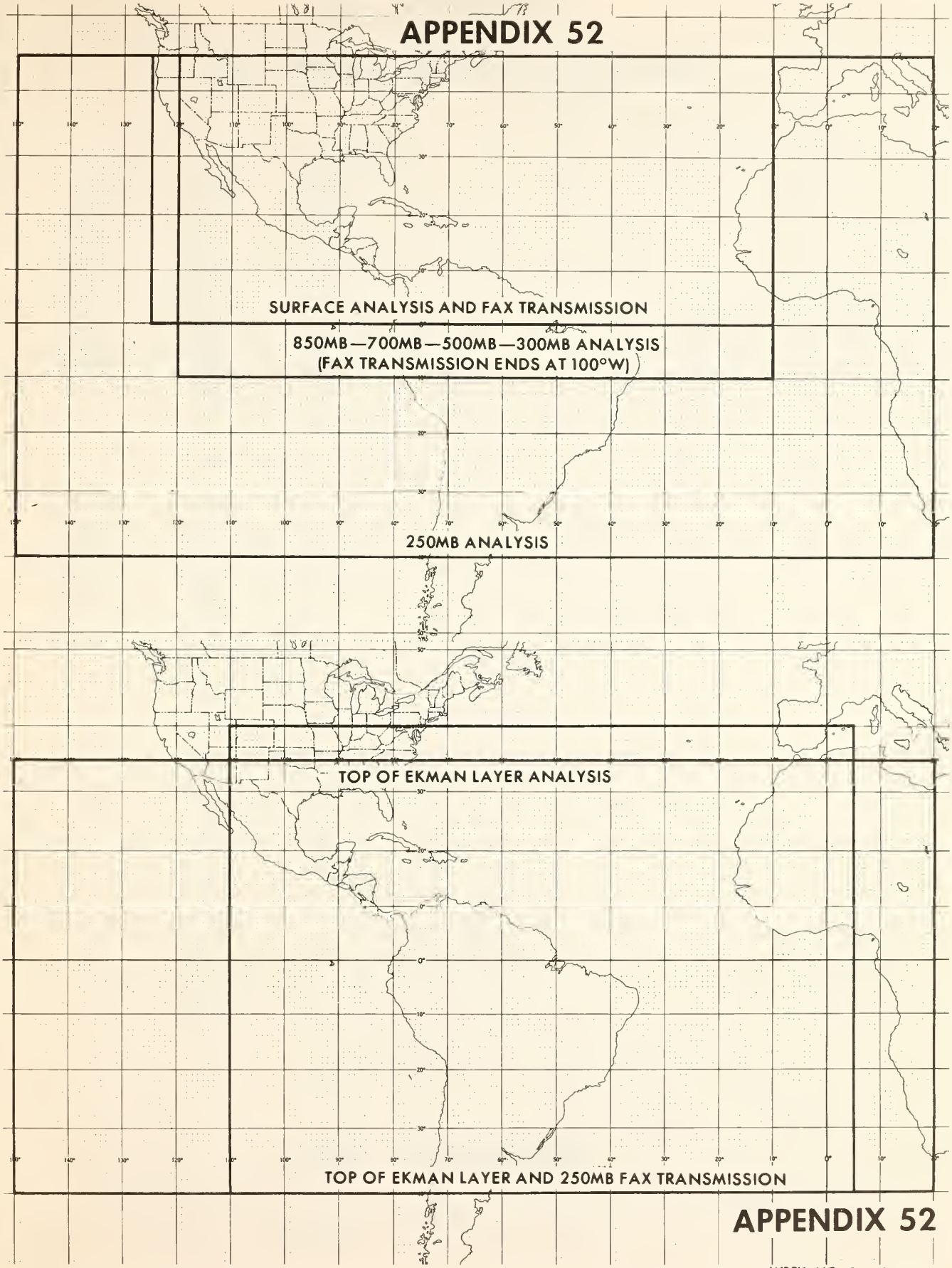
APPENDIX 50

APPENDIX 51



APPENDIX 51

APPENDIX 52



APPENDIX 52

APPENDIX 53

SELECTION OF SURFACE REPORTS USED

Service C #30 SM

74393	78016

Service C #31 SM

72234	72207	72218	72222
312	205	206	202
2/0	308	211	201
310	327	410	
317	326	226	
217	306	220	
228	314	304	
214	324	219	
223	208	231	
	235	232	

Service C #32 SM

72351	72243	72240
258	330	242
255	334	253
241	340	251
263	440	363
356	344	267
348	259	266
265	256	250
262	254	353
261	248	

Service C #35 SM

72378	72374	72290
384	365	280
394	286	278
295	270	274
	271	386

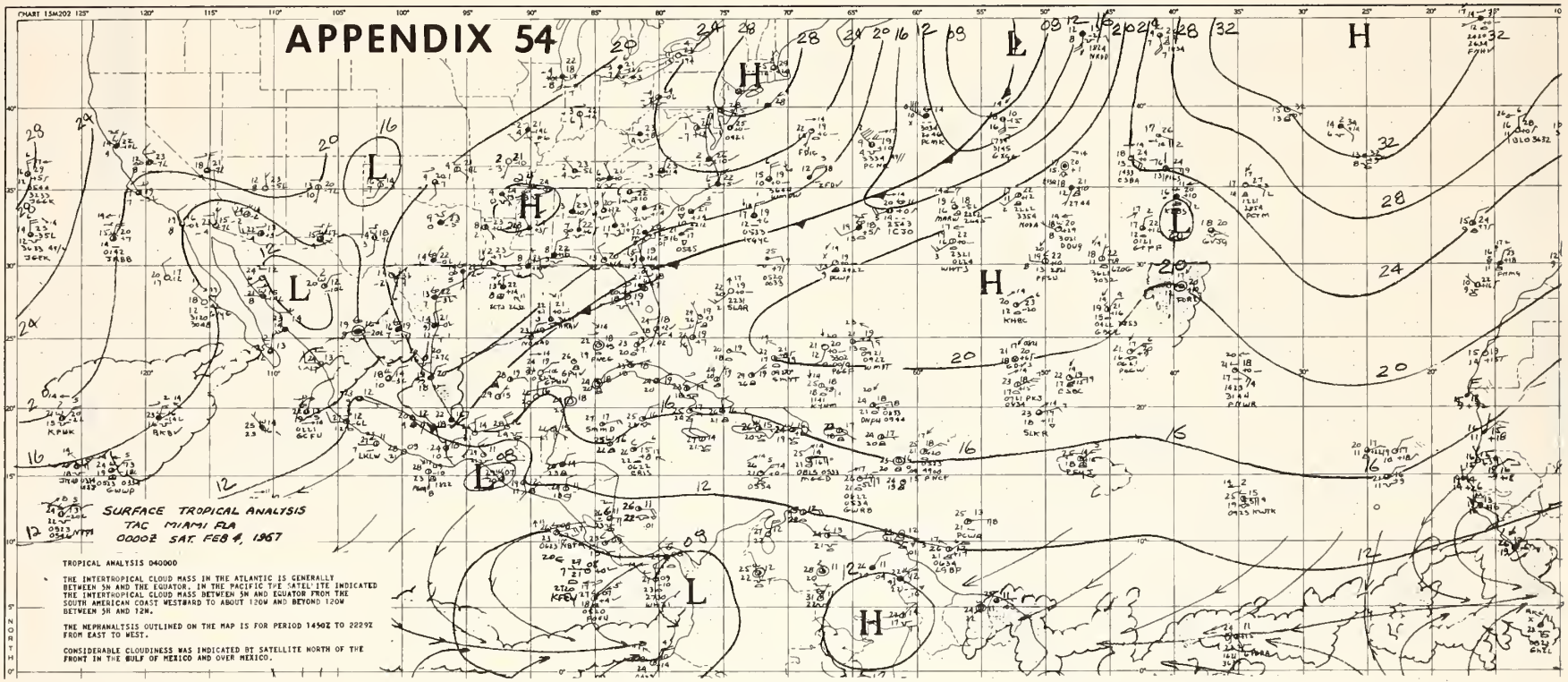
UNSCHEDULED

(No Specific Collection Is Made)

SMCA EYW
SMCA NEW
SMMX ELP
SM GLS
SMVD 1-2-3-4-5
KWBC
SMCA KMIA
SM MIA

APPENDIX 53

APPENDIX 54



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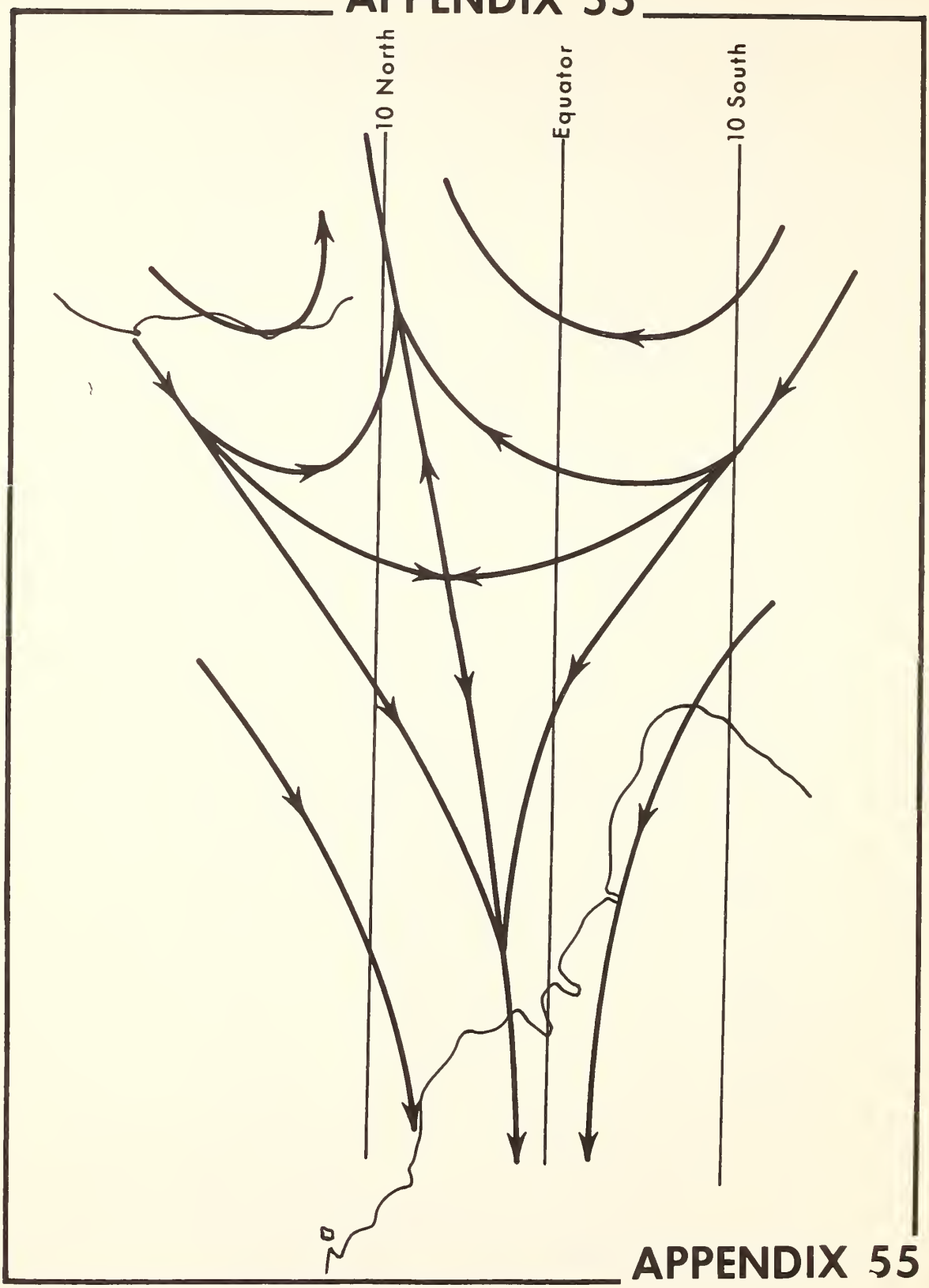
67-1 10-1-67

APPENDIX 55



APPENDIX 55

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